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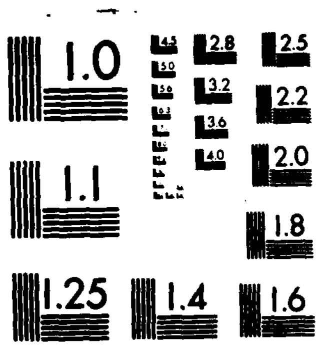
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INTERFERENCE SUPPRESSION FOR AN/SPS-10

AD A129108

Systems Development Division
Westinghouse Defense
and Electronics Center
Baltimore, Maryland 21203

February, 1983

Final Report for Period July 26, 1981 – January 26, 1983

Prepared for

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The AN/SPS-10 is frequently victimized by electromagnetic emitters both on board ship and within the fleet. Most serious interference occurs within its operating band, 5.45 to 5.825 GHz, and the second and third harmonics of its operating band. Susceptibility of the radar system to interference is due to lack of elective receiver preselectivity, intermodulation distortion and saturation within the receiver.

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The following receiver modification recommendations are made:

- Provide narrowband frequency adjustable preselector filter,
- Replace present mixer with high level doubly balanced mixer,
- Provide 80 dB out-of-band IF rejection and high dynamic range operation, and
- Replace AFC mixer with image reject mixer.

The body of the report provides background and specifics concerning the above recommendations. The recommendations can be provided to comply with form and fit and will be functionally equivalent in the absence of interference to the present system. In the presence of interference, the system with the modifications will provide interference free operation except where the interference is directly on its operating frequency (within ± 10 MHz). Effectively, the RF shelf of the receiver will be replaced. Two changes in alignment procedures and some modification of repair procedures will be required to accommodate the improvements.

EXECUTIVE SUMMARY

The AN/SPS-10 is frequently victimized by electromagnetic emitters both on board ship and within the fleet. Most serious interference occurs within its operating band, 5.45 to 5.825 GHz, and the second and third harmonics of its operating band. Susceptibility of the radar system to interference is due to lack of effective receiver preselectivity, intermodulation distortion and saturation within the receiver.

The following receiver modification recommendations are made:

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1. INTRODUCTION

Though the AN/SPS-10 has been a part of the fleet inventory since shortly after WW11, it effectively provides local navigational functions relative ship positions (keeping station) and information useful in detecting and monitoring low flying vehicles. The equipment was designed prior to many improvements which might aid in operation in the recognized dense electromagnetic environment on shipboard. Identification of characteristics of the SPS-10 will be useful both in consideration of measures potentially useful towards its upgrading and also for other equipment with design similarities for similar functions. A brief description and background of the characteristics of the SPS-10 is provided in this section. The scope of the present program was limited to the RF system of the receiver with specific attention to preselection, high level mixing and IF bandpass. The thrust of the background and description as provided are limited to that needed to evaluate the recommendations described in subsequent sections and are not intended to be exaustive. In other sections, for example, the transmitter and IF are described briefly only to the extent needed to discuss a significant interference related issues.

The receiver-transmitter of the SPS-10 is shown in figure 1[1]. The circuit of the crystal mixer assembly is in figure 2[2]. The receiver elements consist of a TR (Transmit-receive) tube to protect the receiver from the high transmitter leakage signal, crystal mixer assembly to down-convert to the 30 MHz IF frequency and a radar/beacon common receiver with two bandwidth options (1 MHz or 5 MHz). The down-converter mixer element is a single crystal diode. All receiver elements are physically located in the Receiver-Transmitter assembly. The receiver crystal mixer assembly also contains the beacon and radar local oscillators, beacon reference circuitry with crystal detector and radar AFC crystal detector.

As suggested by the above, the principal selectivity is provided by the IF amplifier and associated matching and tuning elements. This is the area in which selectivity for the 1 MHz and 5 MHz bandwidth options is provided. Some nominal selectivity is provided throughout the receiver front end from receiver protector to IF. As will become apparent, even this nominal selectivity is important, even though inadequate, in protecting from some out-of-band electromagnetic interference. In fact, selectivity of the SPS-10 receiver might appear to provide considerable protection from interference and possibly would be sufficient were all elements within the receiver linear. With its limited dynamic ranges and susceptibility to intermodulation products, the present system is, unfortunately, susceptible to interference as indicated by ships trouble reports consolidated by NRL [3].

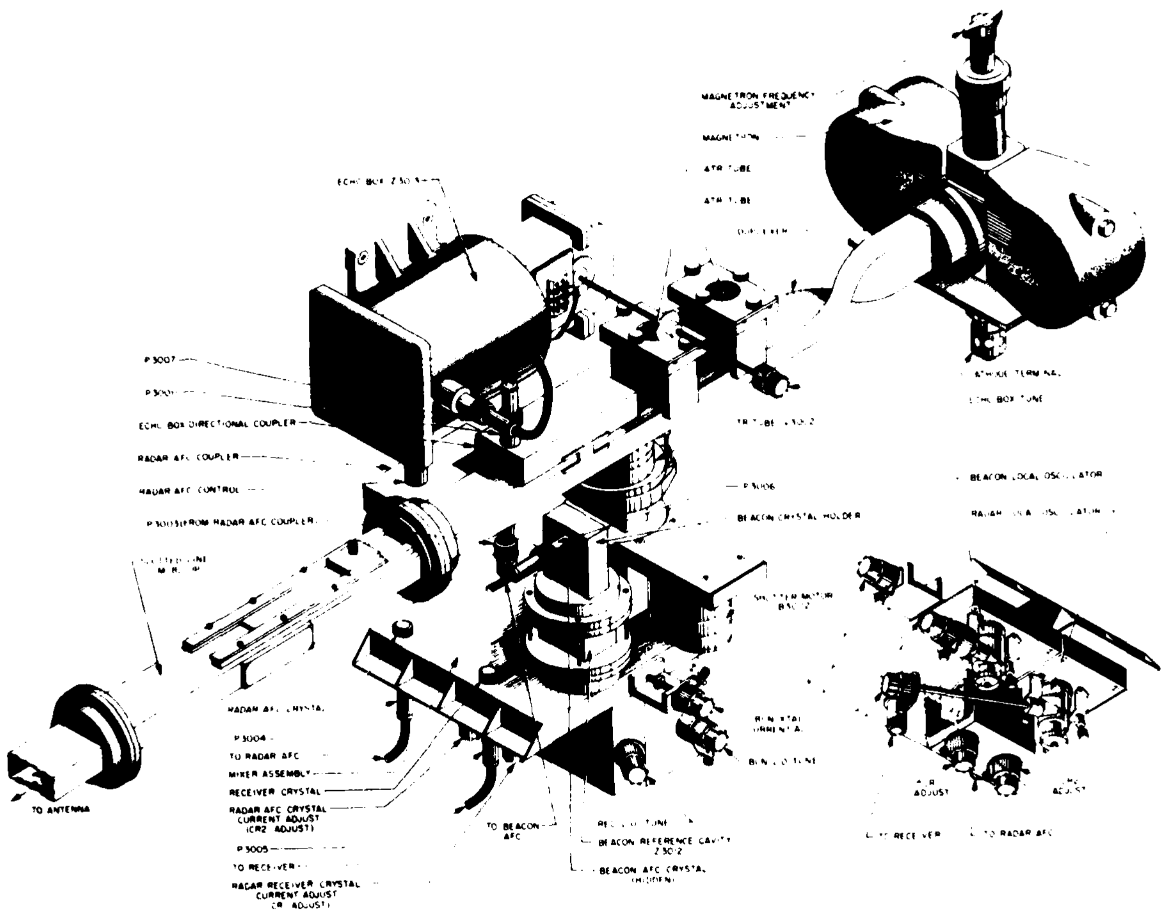


FIGURE 1 Pictoral View of RF System for SPS-10 RADAR[1]

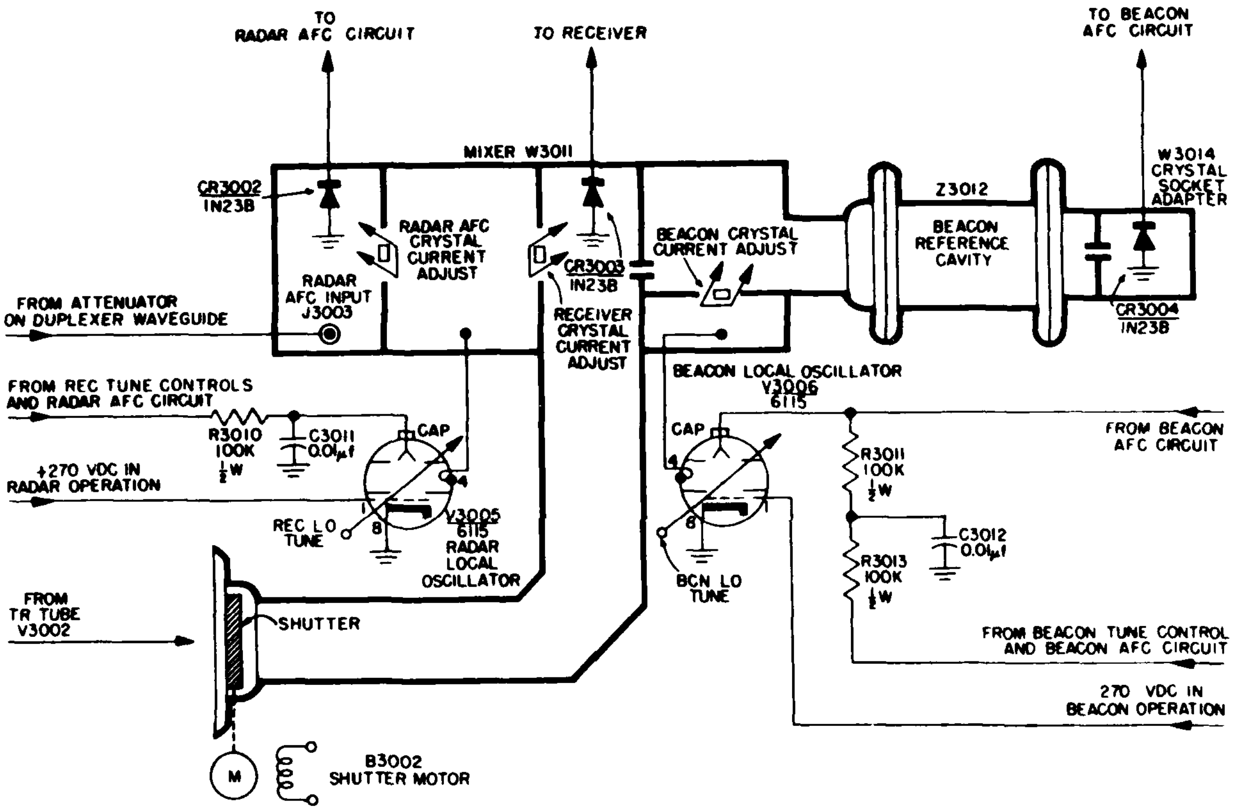


FIGURE 2. Schematic Diagram for Crystal Mixer Assembly for SPS-10 RADAR[2]

2. BACKGROUND AND CHARACTERISTICS OF AN/SPS-10

2.1 Selectivity of Present Receiver

Selectivity of the present receiver is provided by the combination of elements associated with the RF, mixer elements and the IF. The present preselectivity is provided by the transmit-receive (TR) assembly. The bandpass characteristics of the TR is shown in figure 3[4]. This shows an insertion loss of 1-3 dB in the operating band and up to 60 dB isolation out-of-band. No inband selectivity is provided and out-of-band selectivity increases only gradually beyond the band edges. Figure 4 shows an example response covering the complete frequency regions of interest. Though this response is not continuous and represents more than just preselection of the TR assembly, it is indicative of the selectivity afforded by the receiver for the frequency band of interest. This was compiled by combining the response of the TR assembly with the response of the total receiver in selected out-of-band regions of particular interest, particularly harmonic. Again, though this is not exhaustive, it indicates clearly the susceptibility of the receiver to interference both in-band and out-of-band. Based on accepted mixer computations,[5] mixing loss of a signal at the second harmonic of the local oscillator (L.O.) is 6 to 10 dB greater than at the local oscillator fundamented. Mixing at the L.O. third harmonic is another 6 to 10 dB less sensitive than at the second harmonic. Since signals at the second and third harmonics, respectively, are shown in Figure 2-4 to be only 12 and 22 dB less sensitive than the fundamental band, the receiver shows virtually no rejection of frequencies in its harmonic bands.

Figure 4 provides information only on in-band and above-band frequency regions. This is because the system is waveguide fed and waveguide cutoff for size RG 49 used to feed the SPS-10 is 3.15 GHz. The tests were conducted right at the receiver and do not include waveguide attenuation. However, for any practical installation with any significant waveguide run, more than adequate below band-protection is provided.

The mixer portion of the receiver provides very little, if any, selectivity, First, it is of a wideband design. Further, the tests shown in figure 4 show that it responds both in-band and at its second and third harmonics. The fact the response to the harmonics is close to the theoretical response to harmonics relative to fundamental, indicates virtually none, if any, selectivity is being provided by the mixer.

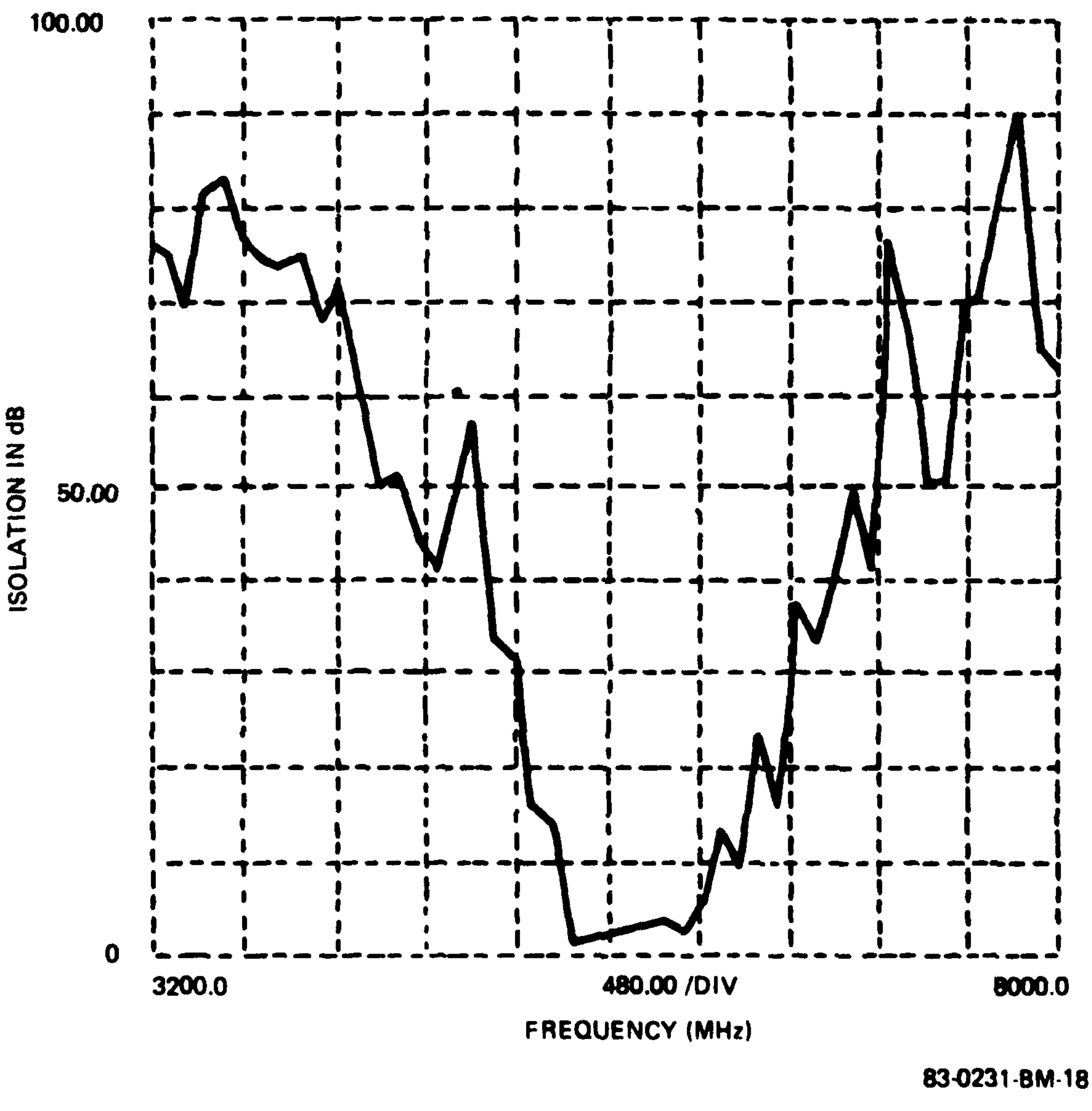


FIGURE 3 Bandpass of TR Assembly [4]

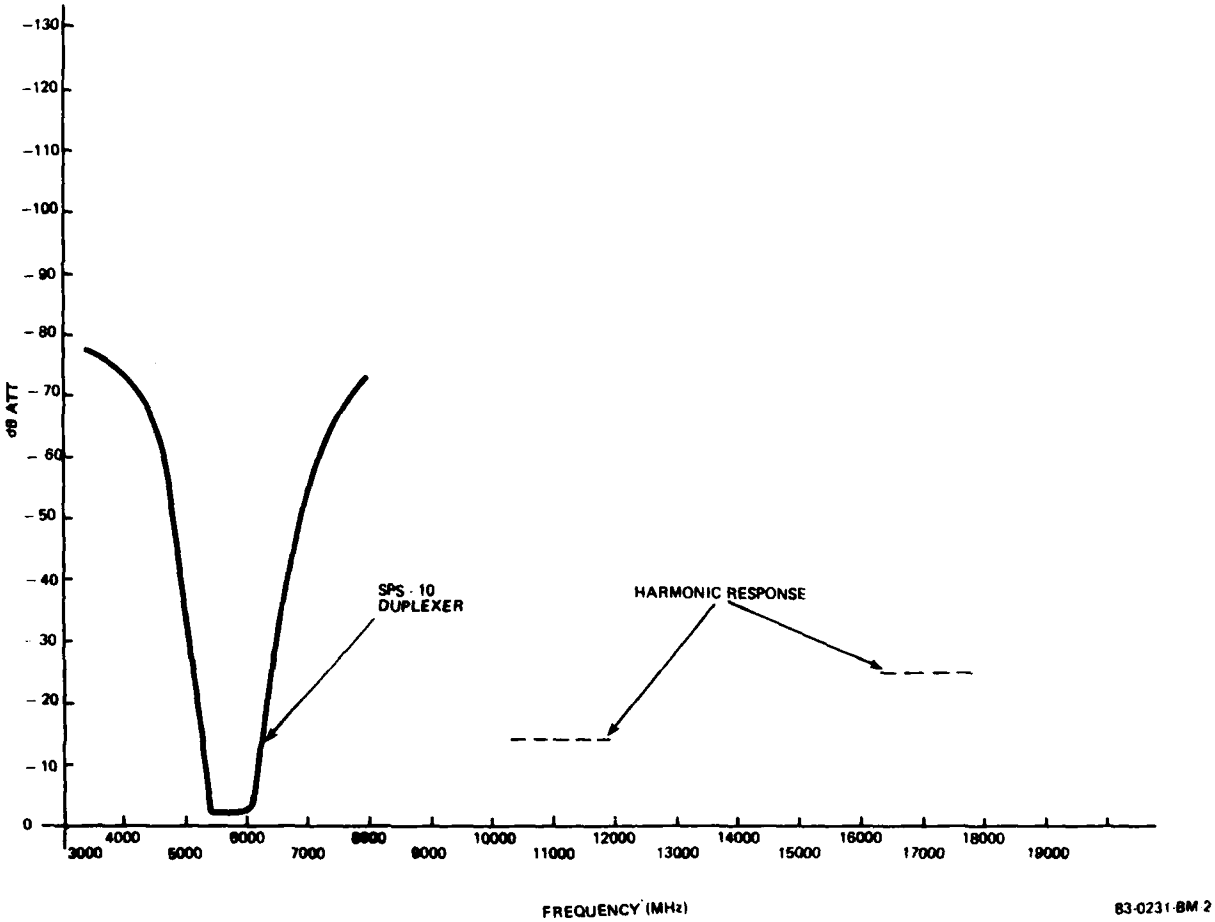


FIGURE 4 Gross Frequency Response of Present SPS-10 Receiver

The remainder of the selectivity is provided by the IF amplifier beginning with the mixer to amplifier matching. Though the mixer to IF matching was not measured directly, its importance was clearly identified because measured composite noise figure was several decibles lower than could be justified by the mixer loss and IF noise figure measured values when the mixer-IF junction was broken for making those measurements.

Low signal IF selectivity is shown in figure 5[6]. Both narrow and wideband characteristics are shown. The bandpass characteristics effectively fit the required bandwidth for each of the operating modes and, again, would effectively provide all needed selectivity were there not the potential for large interfering signals within the overall operating band of the radar. Unfortunately, interfering signals which can pass through the receiver front end can potentially be 100 db greater than the direct radar signal return. The selectivity skirts of the IF are entirely inadequate to exclude this type of interference.

2.2 Intermodulation And Dynamic Range

Selectivity of the receiver has been treated as though the receiver were linear. Clearly, this is not the case and though hints of some elements of nonlinear operation have been made (harmonic response in figure 4) this was done to illustrate selectivity characteristics rather than effects of nonlinearities. Nonlinearities have been recognized as a source of receiver spurious and studies conducted toward their reduction[7]. It will be shown in this section that nonlinearities have a major effect on the operation of the system.

Effects of nonlinearities on frequency discrimination as applied to the SPS-10 receiver are essentially three-fold: (1) those that create spurious signals; for example, intermodulation distortion, (2) those that mask the desired signal; for example, amplifier saturation and (3) those that distort the design selectivity.

Intermodulation or higher order mixer products are present in all superhetrodyne mixers in varying degrees. The purpose of this portion of the discussion is to provide a basis for establishing the degree of improvement possible with an improved mixer and serve as a background for discussion of suppression of residual mixer products by other means.

Figure 6 shows an approximate set of levels of sensitivity of higher order mixer products and images typical the present receiver. Two measured values are also included.[4] Though the precise levels may vary slightly from system to system, and for the power setting of the local oscillator at the time of test, the levels are an indication of what can be expected. The chart is for an LO at 0 dBm. The discrete mixer products of the LO and signals at the indicated frequencies occur for signals related to the LO, signal and image frequencies as shown. The straight line, "Third Order Products" results from mixing other pairs of signals, noise or other signal elements at third order and can occur at any frequency relative to the L.O. Similar lines could have been drawn at the 2x2 level and the signal-image level. Three pairs of signals related in numerous way provide IF frequency output. The actual frequencies of signals so related can be anywhere in the receiver operating band and well away from the actual operating frequency. With so many strong signals physically near the system, the potential for interference anywhere within the pass band of the receiver front end is immense.

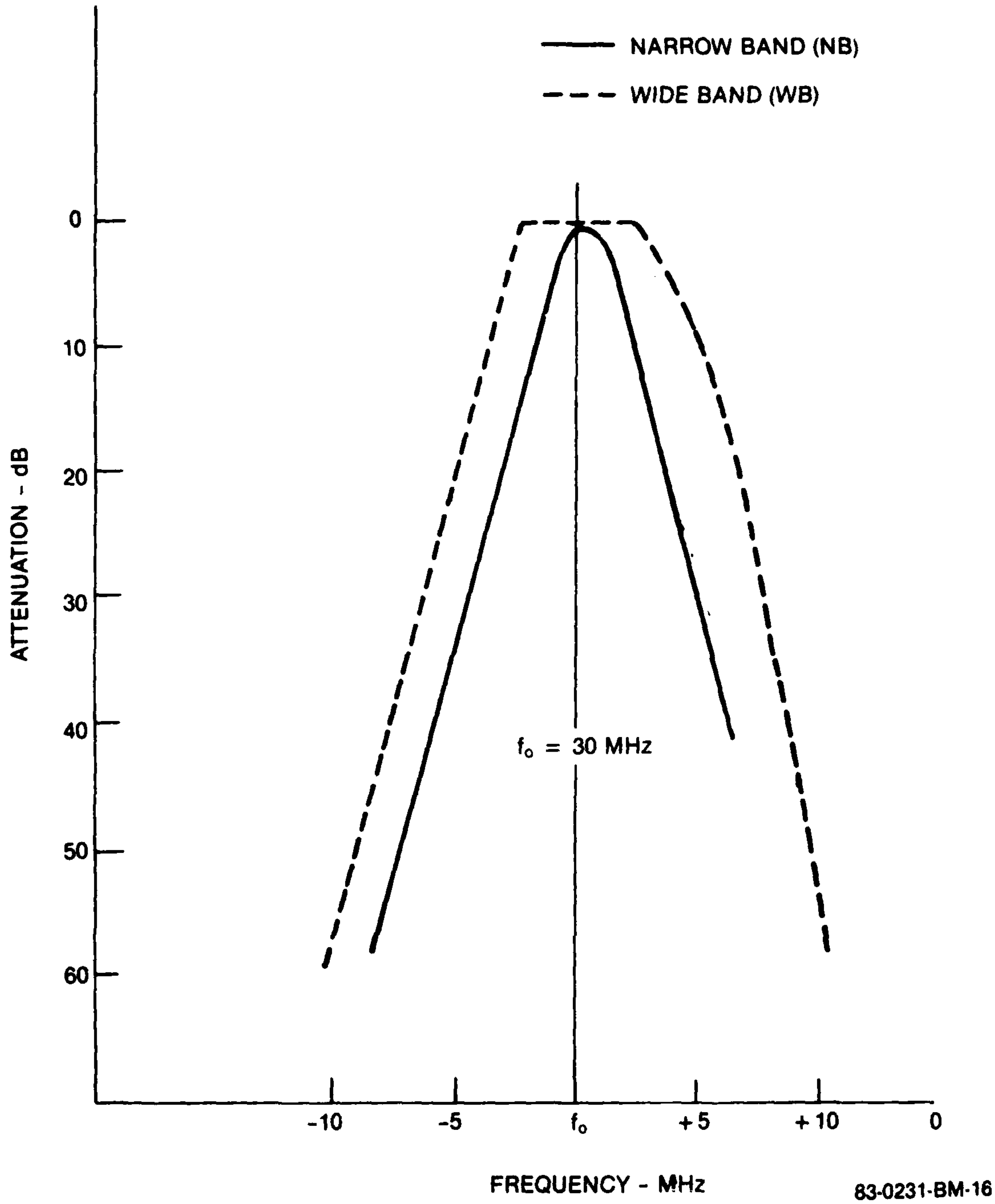


FIGURE 5 Low Level IF Selectivity
in both Narrow and Wideband Positions[6]

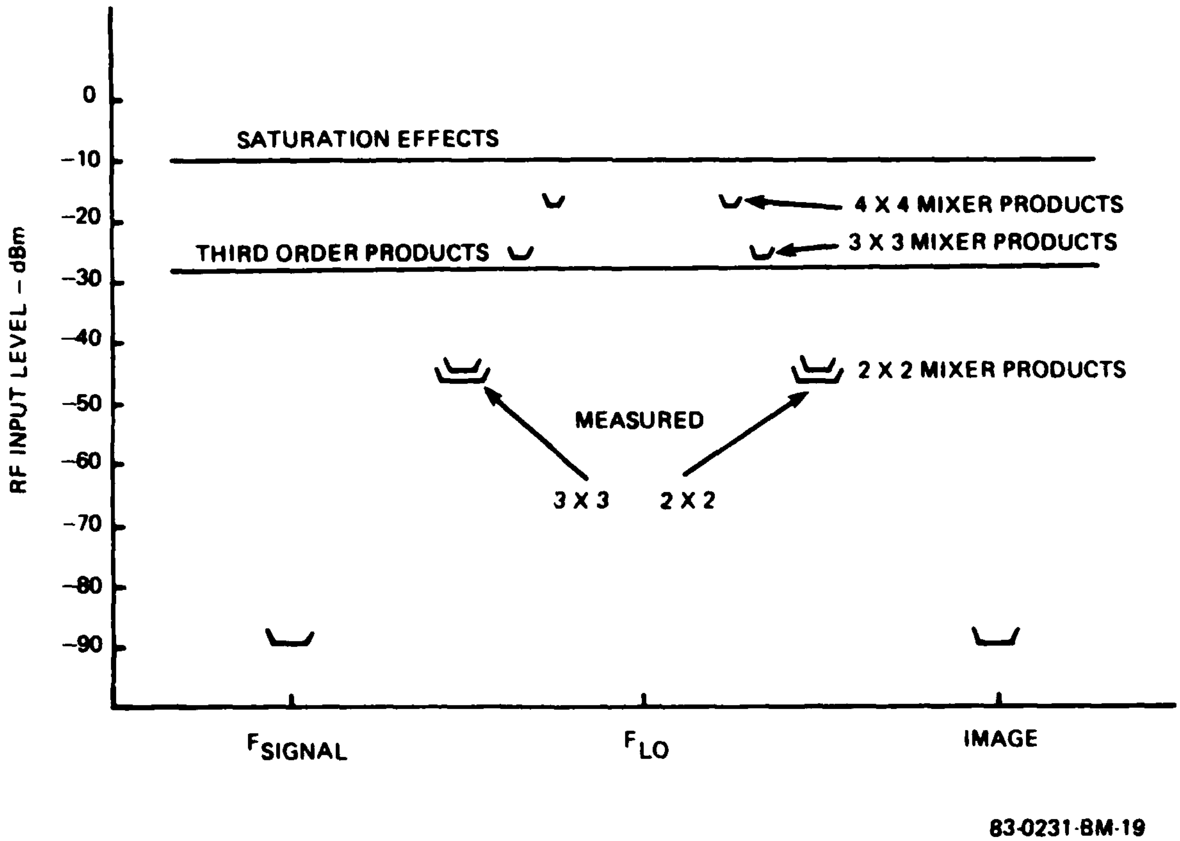


FIGURE 6 RF Interference Level Susceptibility Typical of Present SPS-10 for 6 dB Tangential Sensitivity to Noise Level for 1 MHz Bandwidth Along with Two Measured Levels (NRL)[4]

The designation of mXn of the mixer products indicates the mixer products of each signal and the LO involved in the mixing process. For these cases m and n are equal. They need not be, for example, the harmonic response in figure 4 shows 1x2 and 1x3 mixing. In these cases, a signal actually at the harmonic frequency mixes with the second or third mixer product of the LO. The measured sensitivities of signals in the second and third harmonic bands of the receiver were approximately 12 and 22 dB, respectively, less than the fundamental is consistent with the computational approach used to determine the higher order mixing components.

Saturation in the SPS-10 occurs frequently because of the very small dynamic range of the IF amplifier. The dynamic range of the IF depends upon the gain setting and varies from as little as 10 db to as great as 30 db depending upon the setting. The effect of the gain control on the dynamic range can be appreciated from figure 7[8]. This is a chart of sensitivity range and dynamic range for a series of gain control settings. Since the gain control setting is not scaled, it cannot be included precisely on the chart. Even so, the important quantities are included. This chart shows that for the gain control in its most sensitive range, the dynamic range is only 10 dB. Thus, set to see buoys, it would be totally overloaded by a ship. Though the dynamic range increases with decreasing sensitivity settings, it is never greater than ± 15 dB (30 dB total range) from the center of the setting range. Thus, though it is possible to set the sensitivity for any sized target, it is impossible to set the gain for a wide range of target returns.

The small IF dynamic range adversely affects the system operation in at least two ways, i.e., blanking of targets by interference and shadowing (through blooming) small targets by large targets when the gain is set to view small targets such as buoys.

An additional disadvantage of the very small dynamic range IF is that it limits approaches which can be used to provide interference cancellation. There are approaches to analyzing the receiver signal and deleting unwanted signals or unwanted portions of a signal. The effect of such approaches is normally to blank interference or other unwanted signals which can be so identified. Unfortunately, with such a small dynamic range IF, any such approach which depends on detecting such a signal at the output of the IF has already experienced much of the damage of the interference. Such interference, even though identified and deleted from the presentation, may still mask geniune targets in the area. Thus for most effectivenss of such interference cancellation approaches, a high dynamic range receiver is required.

Present IF selectivity, based on a selection of two bandwidths as shown in figure 5, is 5 MHz and 1 MHz for two switch settings. The bandwidths for the IF are appropriate for the pulse lengths, .25 us and 1.0 us of the RADAR.

The problem with the IF is the lack of a deep skirt selectivity and dynamic range. Signals can be transmitted by the receiver front end which displays at least 80 dB dynamic range differences. More to the point, if improvements to be suggested later are carried out, dynamic ranges over 100 dB between signals can be expected at the IF. The skirt selectivity as shown in figure 5 simply does not significantly discriminate against signals larger than the IF dynamic range.

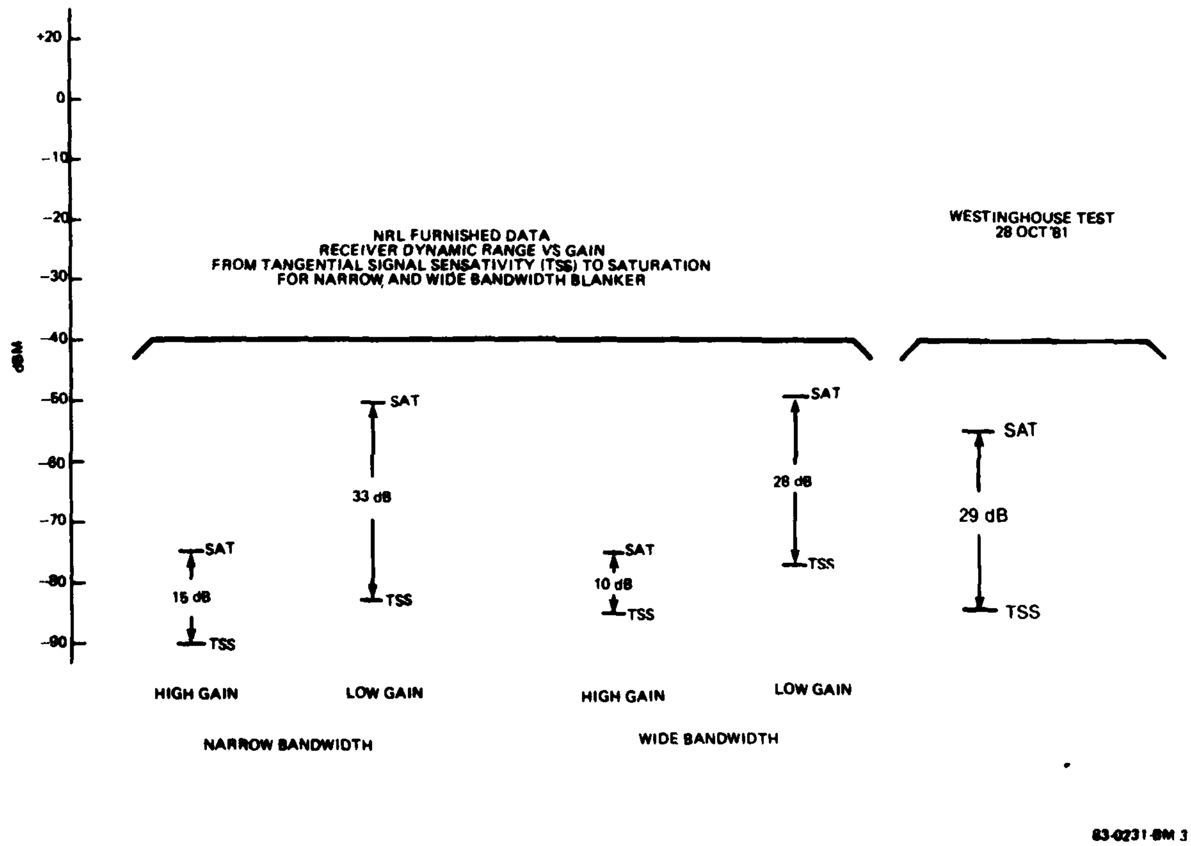


FIGURE 7 Chart of Receiver Dynamic Range and Sensitivity Range for a Series of IF Gain Settings [8]

An operational nuance which can, if ignored, lead to further loss of IF selectivity is based on the operation of the AFC. The present AFC provides a means of locking the receiver to the transmitter magnetron frequency through a 30 Mhz offset. This capability is operationally desirable because the magnetron can jitter more than an acceptable amount relative to the IF bandwidth. Unfortunately, the AFC can lock up either above or below the magnetron frequency. For normal alignment, the local oscillator is tuned above the magnetron. For this condition the polarities of the AFC error voltage is appropriate to hold the LO very close to the sum of the magnitron and IF frequencies, as illustrated by the discriminator response in Figure 8[9]. With LO above the magnetron frequency an IF signal above 30 MHz calls for a decrease in the LO and vice-versa. By contrast if the LO is below the magnetron frequency, an IF signal above 30 Mhz calls for an increase in the LO, set so that a positive discriminator response decreases the LO (appropriate for the LO above the magnetron), if the LO is set below the magnetron, the LO will be pulled further off, increasing the IF frequency to the upper edge of the S curve. The same thing in the opposite direction occurs if the IF is initially below 30 MHz. Thus when the LO is tuned below the magnetron, the AFC attempts to hold the IF frequency at one or the other edge of the S curve or up to 5 MHz off the magnetron frequency.

The effect of control of the IF frequency off 30 Mhz is illustrated in Figure 9. The signal is shown centered above 30 MHz. It might appear that the problem would be readily apparent to the operator. (See Appendix Section 7.3.2 second paragraph). However, because sufficient gain is available, in the absence of signals at the IF center band, the RADAR may appear reasonbly normal. It does, though provide a band in which the IF is more sensitive to certain interference frequencies than to its own radar return.

2.3 Transmitter

Though outside the scope of this study, serious consideration of the operation of a significant number of radiating systems such as the SPS-10 in resonable proximity can not be comprehensive without consideration of the transmitted spectrum. Two objectives in relation to the transmitted spectrum are pertinent, first, maximum concentration of the spectrum within the receiver bandwidth and minimum mutual interferance between systems operating within range of each other and, second, consideration of the improvement in signal to noise ratio from cooperative or matched filter techniques between transmitters and receivers.

The seriousness of the transmitter spectrum is illustrated by Figure 10[10]. This spectrum taken from a system operating in the fleet shows significant emissions over a band greater than 1 GHz centered on the operating frequency. Within this band the noise floor is no where less than 30 dB below the carrier and shows peaks only 22 dB below. For these tests the detection bandwidth was 100 KHz. The extent of the noise floor beyond these limits was not shown. The report suggests a need to align the radar and possibly replace the magnetron. The example, none the less, indicates the seriousness of emissions from significant systems in the inventory relative to achieving relatively interference free operation of system in ship and fleet proximity.

In its present form the transmitter precludes any possibility for transmit recieve matched filter operation. Requirements for matched filter operation will be discussed briefly in Section 3.5.

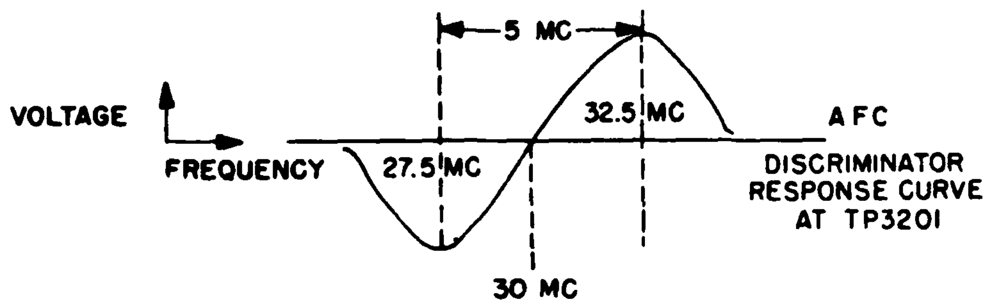


FIGURE 8 AFC Discriminator Response Curve[9]

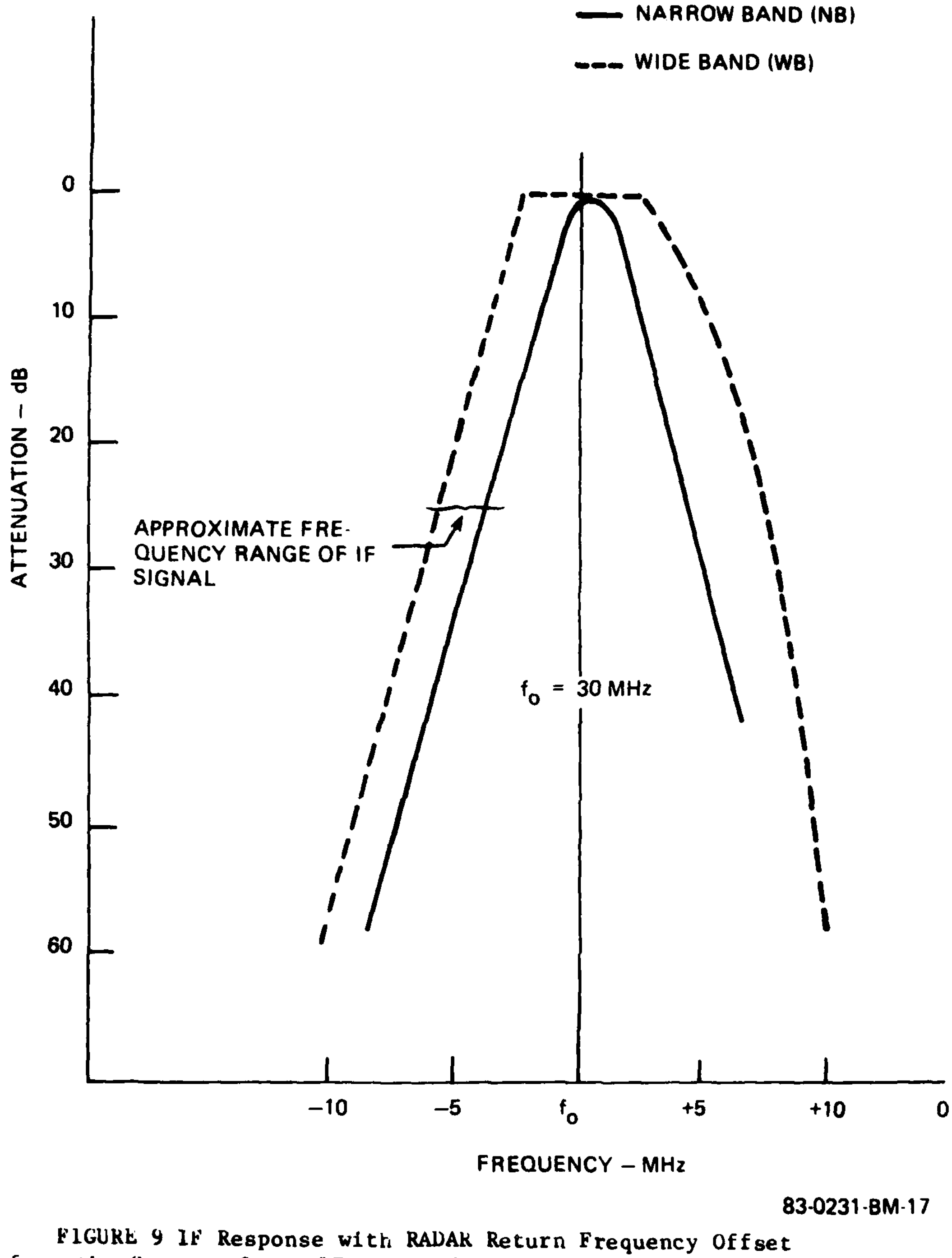
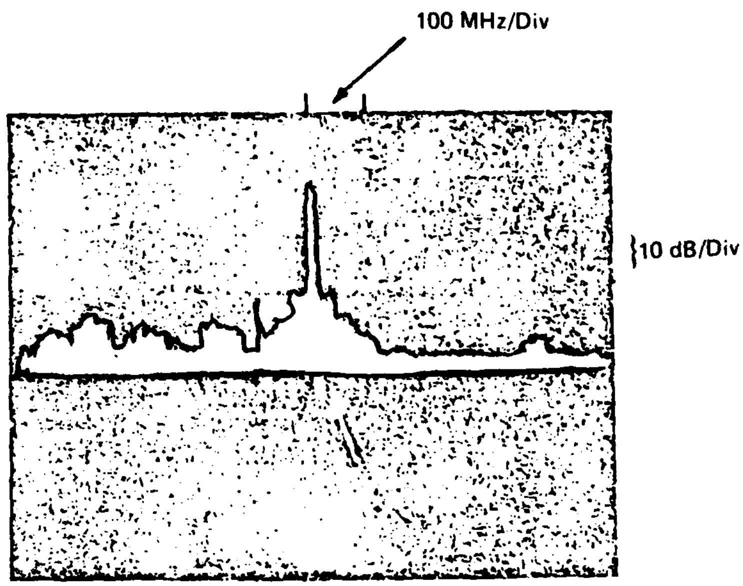


FIGURE 9 IF Response with RADAR Return Frequency Offset from the Center of the IF Band. This can occur as a result of alignment of the LO frequency below the magnetron frequency.



f_o = 5.68 GHz
Log Ref = 40 dBm
Ext. Attn. = 40 dB

BW = 100 kHz
Scan = 100 MHz/Div

Figure 10 - Measured reponse of SPS-10 transmitter magnetron illustrating a spectrum 1 GHz wide. Noise floor is no where more than 30 dB below carrier and lobes are only 22dB down.[10]

3. APPROACHES TO ELECTROMAGNETIC INTERFERENCE SUPPRESSION

Two broad categories of interference suppression can be considered in improving operation of electromagnetic systems in dense signal environments. Those are (1) improved selectivity and, (2) processing or cancellation of interference that is received. Both approaches can be used with equipments operating cooperatively, for example, on a ship or can be individual to a single system. Cooperative approaches are clearly essential to achieve the maximum in operability in dense signal environments. When this is not possible or is possible to a limited degree only, equipment can be optimized for operation in dense environments. This study was limited to measures applicable to the receiver of equipments which must operate in a dense environment.

Though limited to the receiver, both improved selectivity and signal processing provide viable potential benefits. The thrust of this study has been improved selectivity for which greatest report coverage is given. Processing techniques and their benefits and problems will be briefly reviewed and will be included in the recommendations.

3.1 Preselectivity

Clearly, greatest benefit is achieved by keeping unwanted signals out of the receiver if it is technically, operationally and economically viable. Technical viability clearly depends on bandwidth realationships between potential interference and the desired system signal and available filter selectivity and skirt isolation properties. The SPS-10 operates over the band 5.45 to 5.825 GHz. Present preselection is provided by the duplexer for which the bandwidth is over 600 MHz, more than covering the operating band. The instantaneous bandwidth of the receiver is either 1 or 5 MHz depending upon the operating mode. A minimum practical preselection bandwidth, which must be broad enough to pass the magnetron signal including normal instability, can be as low as 15. This is based on the stability of the magnetron transmitting tube. Immense improvement in interference signal freedom can be achieved by closing the band from greater than 600 MHz to 15 MHz. This would be true even if inband response were the total potential for interference. This is only partially true, as was illustrated in figure 4, the actual band of susceptibility extends from just below the operating band to greater than the third harmonic. Within these bands both direct conversion, harmonic conversion, signal pair conversion and receiver saturation can occur due to unwanted and overpowering signals incident on the system receiver. Each carries significant interference to the operating requirements of the system.

Figures 11 and 12 illustrates an approach to preselectivity. Repeats of figure 3 and 4, they are the response of the duplexer showing the operating band and the total band of susceptibility under consideration. Superimposed on these bands is the bandpass of the preselector proposed as a result of this study. Criteria are that it be as narrow band and high out of band attenuation as possible without otherwise degrading performance. The bandwidth selected is 15 MHz. Any number of possible figures of merit concepts might be devised to establish the improvement provided by such a preselector. All would be oversimplifications since the manner in which interference occurs can be very complex. Taking the relative preselector to present duplexer bandwidths offers a crude measure, this would be 15 MHz/600 MHz=0.025.

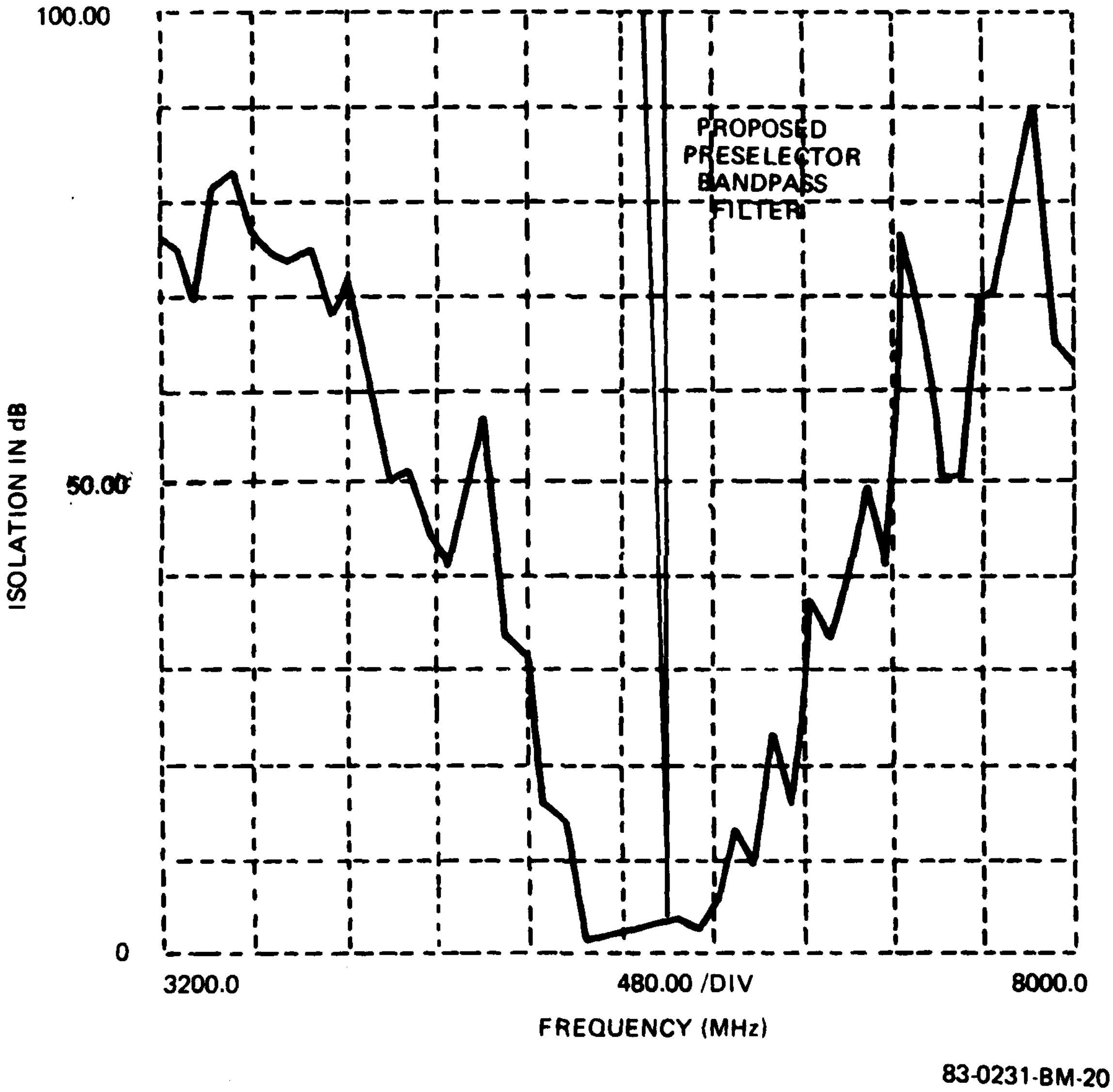


FIGURE 11 Bandpass of Present Duplexer Showing System Operating Band with Proposed Preselector Superimposed.

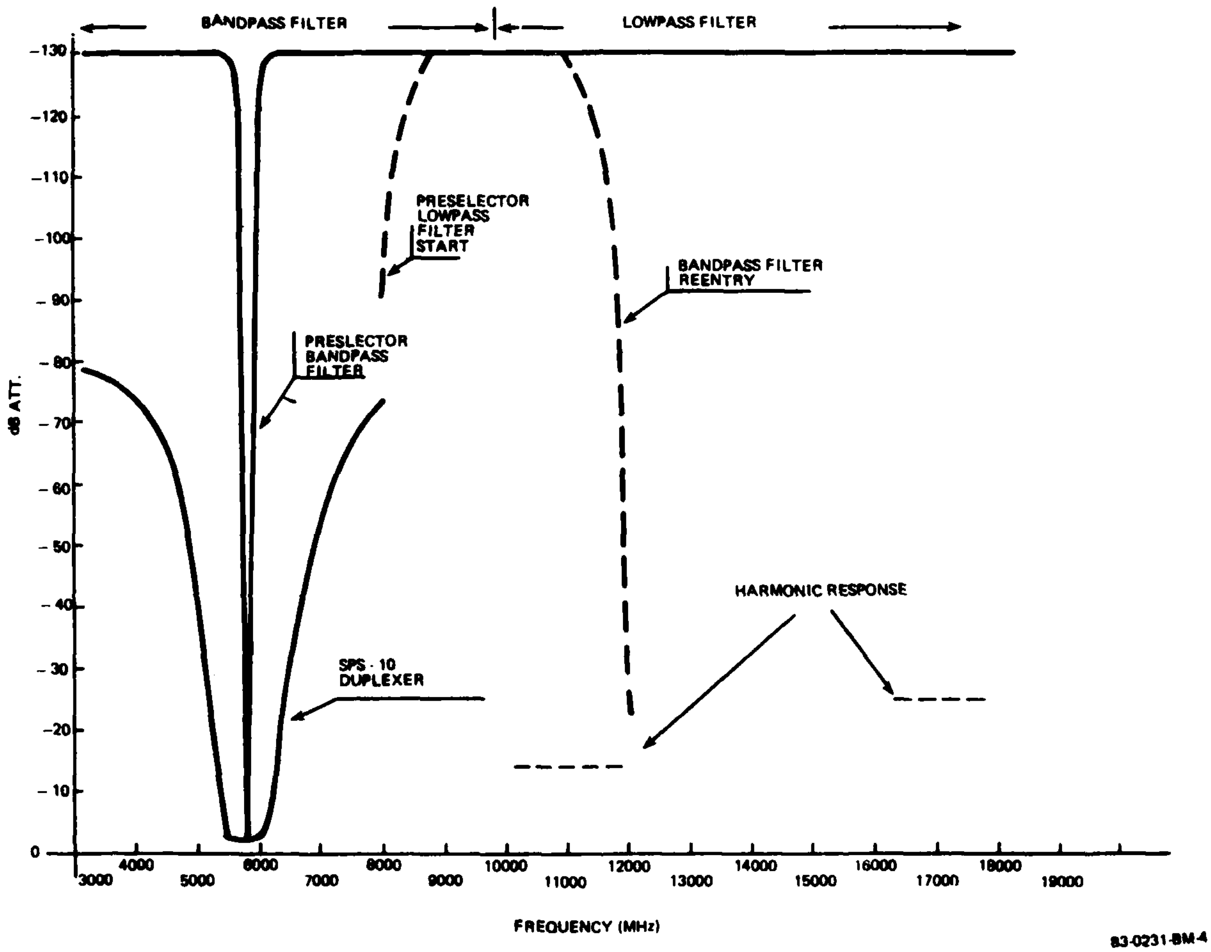


FIGURE 12 Bandpass of Present Duplexer Showing Spectrum From Operating Band Through 20 GHz with Proposed Preselector Superimposed.

This, however, ignores the much greater skirt rejection of the proposed preselector, 130 db to 80 dB, and the fact the proposed preselector filter maintains out-of-band isolation of over 130 dB through 20 GHz. Though no detailed out-of-band response of the duplexer was taken, sufficient points were taken to establish its susceptibility to harmonic conversion with virtually no evidence of preselection as suggested by the harmonic response levels shown in figures 4 and 12. Both these figures show harmonic response levels in relation to fundamental conversion which would be predicted for 1x2 and 1x3 mixing in the absence of significant other attenuation. Measurements taken of harmonic response are described in the Appendix, Section 7.2.

A proposed circuit arrangement for the preselector is shown in figure 13. The key feature is a switching arrangement which allows the preselector to be switched from the circuit for tune-up of the system. Once the system is tuned by present procedure, the preselector is switched in and tuned for maximum response of the system return. An approximate tuning curve would be provided to permit rapid tuning to frequency with only final tuning requiring observation of the display. This approach is proposed as the most practical as it avoids complicated ganging of the preselector with the present magnetron. It also avoids other forms of complicated electronic approaches to automatic tuning deemed to be unwarranted for a system of the design format of the SPS-10.

Selectivity of the proposed preselector is based on achieving maximum selectivity (minimum bandwidth and maximum skirt isolation) consistent with smooth operation and acceptable insertion loss. Smooth operation is defined such that the filter is sufficiently wideband so that settings will hold so long as system remains at an established frequency. Acceptable insertion loss is defined as a level, which when combined with the budgeted insertion losses for all proposed circuit changes, will not increase the noise figure above that of the present system. That significant insertion loss can be incurred by the proposed preselector filter as well as other components is made possible by the proposed mixer (discussed later) with a much lower conversion loss than the present mixer. An insertion loss of 4 db is budgeted for the preselector filter.

The preselector proposed contains both a bandpass and a low pass filter so as to maintain high out-of-band isolation from below the operating band to over 20 GHz. An example bandpass, the bandpass used to test the approach, is shown in figure 14. Shown is the bandpass from center band to full shoulder isolation. The out-of-band isolation is equal to 130 dB or more for the range indicated. Design curves are shown in the Appendix, Section 7.2.2

3.2 LOW CONVERSION LOSS, HIGH DYNAMIC RANGE MIXER

A replacement mixer is proposed for two purposes: (1) for lower conversion loss and (2) high dynamic range. The noise figure of the receiver and thus minimum detectable signal are a function of the IF noise figure and all preceeding losses including the mixer. The present noise figure of 16-18dB is based on the present mixer conversion loss of approximately 13-15dB. The proposed preselector and associated circuitry (switches and isolators) will incur added insertion loss of approximately 7 dB. This can be compensated with a readily available high dynamic range mixer with conversion loss of 6dB or more than 7 dB less than the present mixer.

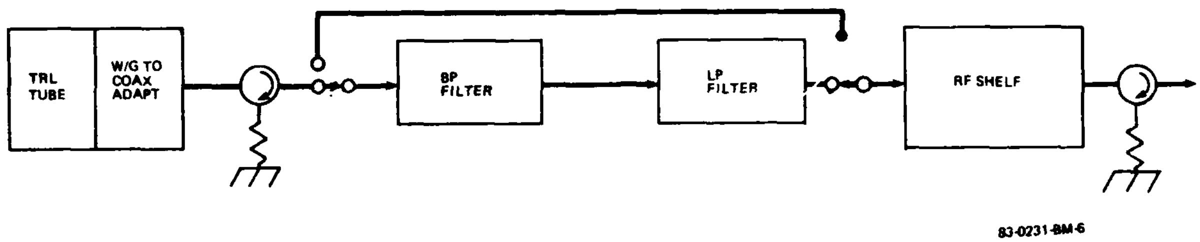


FIGURE 13 Abbreviated Block Diagram of System Showing Proposed Preselector Band Pass Filter/Low Pass Filter Combination.

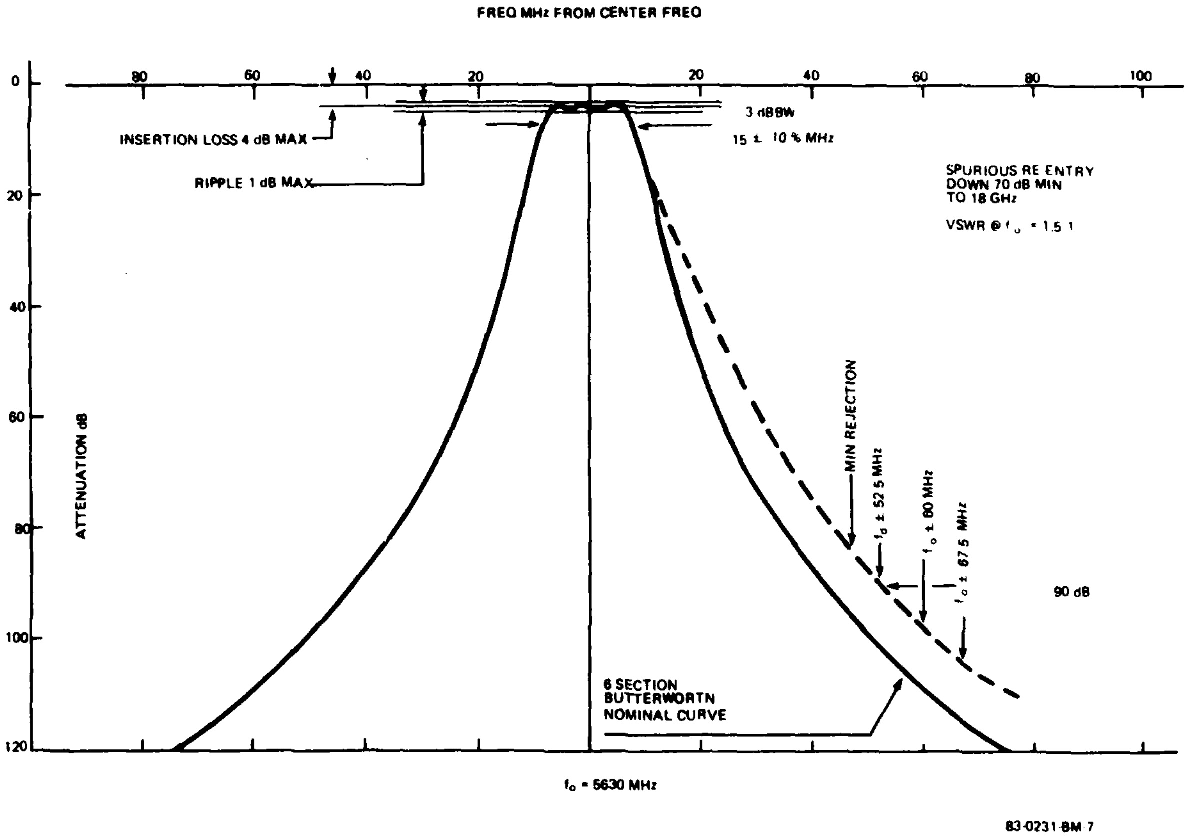


FIGURE 14 Banapass of Proposed Preselector Filter

A replacement mixer is also recommended for high dynamic range. On shipboard with equipment in close proximity, both on the host ship and other ships in the fleet, a very high dynamic range of signals is inevitable. The skirts of the proposed preselector filter rise to 130 dB at approximately 90 MHz from center band (180 MHz bandwidth). From the 3 dB bandwidth of 15 MHz to the 180 MHz bandwidth signals of varying intensity relative to the radar return can enter the receiver. Subsequent selectivity, such as the IF, can only be effective provided large signals near the band pass through the receiver linearly. Any saturation creates its own spurious and defeats the purpose of IF selectivity. The present mixer provides a dynamic range of approximately 75 dB, significantly less than the full skirt isolation of the proposed preselector filter. A high level mixer can provide up to 100 dB dynamic range. Such a mixer is proposed. Table 11 provides the characteristics of the proposed mixer.

3.3 IF BAND RESOLUTION

Two problems were cited in section 2 which require attention if optimum IF band resolution is to be achieved. These are: (1) the fact the AFC can be tuned up with the LO frequency below (for correct tuning the LO frequency is above) the magnetron frequency without its being detected and corrected by the operator and (2) the poor skirt selectivity and dynamic range of the IF. Both must be corrected to meet the objective of this program.

The most straightforward way to assure tuneup with the LO frequency above (the correct side of) the magnetron frequency is to replace the present AFC single diode mixer with an image rejection mixer. This approach has the advantage that no change in operating instructions would be necessary. Since no AFC response curve will occur for the LO frequency below the magnetron frequency, tuneup there simply won't occur. The operator will simply keep hunting until the correct response is obtained (*LO above the magnetron* frequency). The residual response to the image should cause no operating problem since it will be at least 20 dB below the normal response and will appear to be spurious to the operator.

Assuring the desired signal is tuned to the IF band center, minimizes interference relative to the capability of the present IF. Achieving a selectivity appropriate to the range resolution and signal bandwidth requires IF filter skirts and an IF dynamic range appropriate to the dynamic range of anticipated signals. The dynamic range of anticipated signals may be over 90 dB when the system is set for minimum detectable signals.

Two approaches can be used: (1) provide a pre-IF selector or (2) replace the IF with an updated unit. The first approach would make use of a multiple LC filter or a SAW filter and replace the loss with a preamplifier in combination with the filter. Figure 15 illustrates suggested bandpass characteristics superimposed over the present characteristics. The improvement provides both greater selectivity for present skirt isolation, and higher skirt isolation. Skirt isolation for the IF close to that of the receiver preselector is needed.

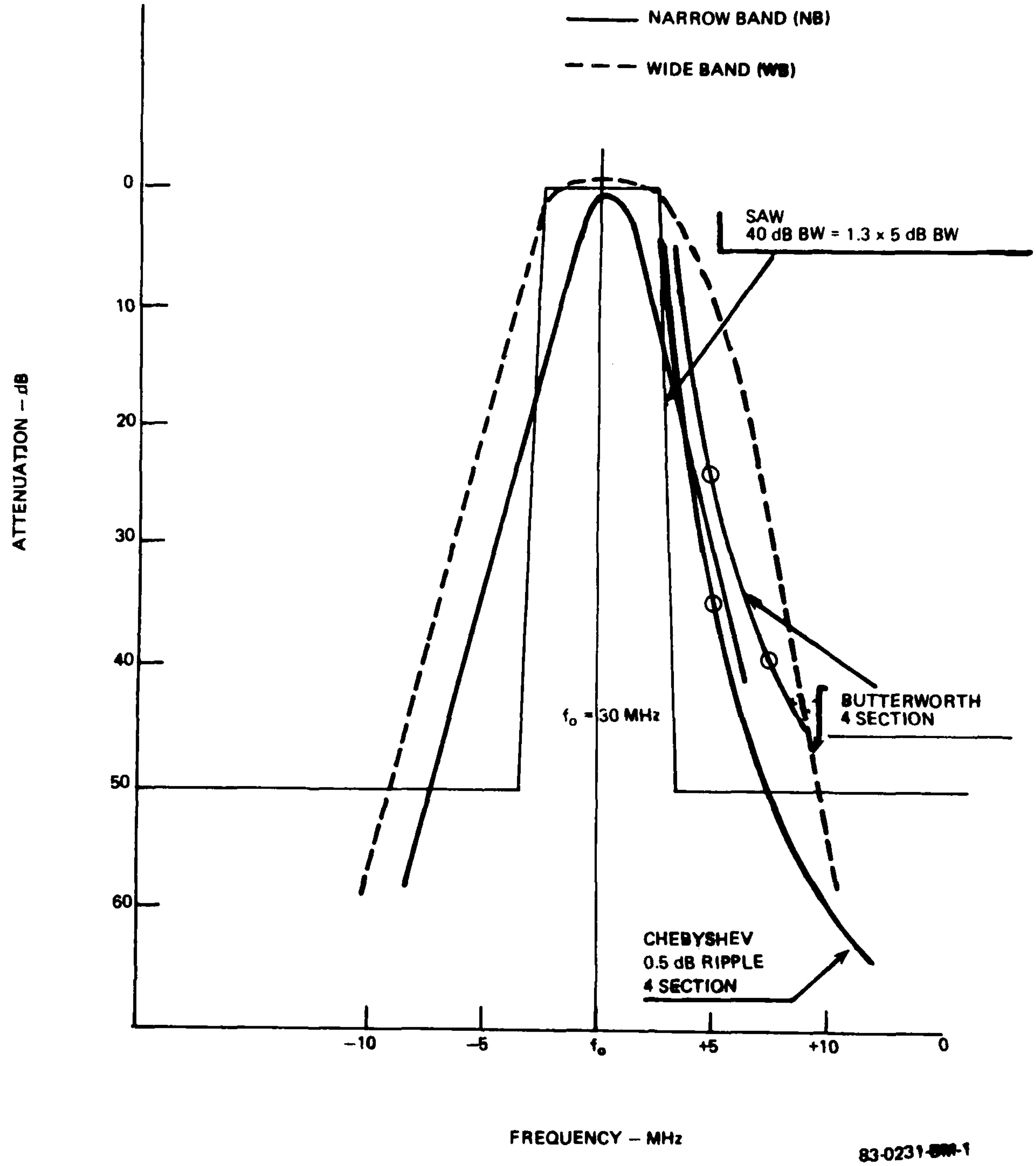


FIGURE 15 Bandpass of Present IF and Suggested Prefilter/IF Options for Wideband Mode

Replacing the IF with a selective high dynamic range IF would provide best performance. Even though an IF preselector would reject most off-frequency interference, it would not handle large dynamic range variation in on-frequency signal return. This can occur from large cross section targets or another system on the same or very nearly same frequency. In either event, the present IF overloads and loses considerable area in the display. Unfortunately, not only does the large signal block the IF during its immediate incidence, but it is subject to overloaded for its relaxation time. It thus blocks the IF for the saturation relaxation time to desired signals.

TABLE 1 CHARACTERISTICS OF PROPOSED DOUBLE MIXER

High Level LO Power (min)	+13dBm
Conversion Loss (max)	6dB
1dB Compression Point	9dbm

The proposed solution to this problem is a high dynamic range IF. The high dynamic range IF will solve the problem of IF saturation, but will not solve the problem of video saturation. A solution to this problem is a combination high dynamic linear range and logarithmic IF. The proposed approach would be for the IF to operate in the linear form except when it is necessary to remove a signal saturating the video. A spring return switch would allow switching to the log IF to momentarily peer past the saturating (which causes the display to bloom) return. This assures that an enlarged obstruction normally will be seen on the display as a large area but in the logarithmic (spring return) position will allow seeing small nearby targets such as channel markers.

3.4 BLANKING TECHNIQUES

Blanking techniques which depend on pre or post IF detection processing can provide significant reduction in the appearance of interference on the system display. In fact, such approaches would provide highly satisfactory results provided smaller signals, normally representing small targets) are not masked. It should be recalled that the concept of a high dynamic range/logarithmic IF switchable combination was proposed in the previous section to avoid masking where legitimate targets of greatly differeing radar cross section are in close proximity.

Blanking works well when several conditions apply:

(1) The percentage time in which interferring and excessively strong signals occur is a small percentage of the total viewing time.

(2) Strong on-frequency signals are not blanked.

(3) The blanking command is not dependent on processing a signal which must be transmitted through a low dynamic range receiver before processing.

(4) Providing the signal to be blanked does not have to be transmitted through a low dynamic range saturating receiver with a long recovery time. Because of the potential for significant improvement in operation through interference with the use of blanking techniques, it is important that the above limitations and their minimization be understood.

3.4.1 Discussion of Blanding Compatible Conditions

Minimization of Blanking Time: In a dense interference environment, it has been shown that if general blanking of large off frequency signals is carried out, up to 50% of the viewing time can be blanked. This same study shows that if blanking occurs for only nearby frequencies, the percentage of blanking is reduced to 5%. Thus, it is imperative that an effective preselection be provided for effective off frequency suppression. The combination of the receiver preselector and IF selectivity proposed by this report will provide this needed selectivity. It is most important that this preselectivity be provided because key nautical targets otherwise may be missed with unfortunate results due to blanking.

Avoidance of Blanking Strong On-Frequency Signnals: Strong on frequency signals are typically the result of large radar cross section return. The return can be from ships or other large objects such as bridges and land masses. Any approach which blanks off-frequency signals will be susceptible to blanking large on-frequency signals. To avoid this problem care must be taken to design adequate selectivity and resolution against blanking large on-frequency signals. An approach to blanking off-frequency signals, the spectrum centered receiver (SCR), is already installed on many SPS-10 systems.[11] Though this receiver does blank off-frequency signals, it is also susceptible to blanking large on-frequency signals. This receiver will be discussed in greater detail in section 3.4.2.

Processing Or Blanking After Passing Through Saturating If Amplifier: Blanking or processing the blanking command signal from an input which has passed through a saturating amplifier will be distorted to the extent that the saturating amplifier recovery is not instantaneous. If saturation masking should be distributed in several aszimnths, a major portion of the display could be masked.

3.4.2 Approaches to Blanking

Two forms of blanking are already installed or under study elsewhere. The spectrum centered receiver (SCR) is already installed on many SPS-10 systems[11]. It provides for blanking signals more than 3 Mhz from the center frequency of the system. It accomplishes this by use of a tuned filter with a band stop at the system frequency. Any signal passing through the filter with strength greater than a predetermined threshold is blanked. Unfortunately, an on frequency signal from a large cross section target also can be blanked. Further, blanking occurs after the regular signal passes through the saturating IF presently in the system. Thus, the present SCR receiver suffers

from a major deficiency, which is correctable. The blanking command should be the result of a signal strength comparison between two filters, one with a band stop and one with a band pass at center frequency. If the signal through the band stop channel is greater, blanking is commanded. If the signal through the band pass channel is greater, blanking is not commanded no matter how large the signal is. With this arrangement, a strong target return will never be blanked no matter how large a genuine target return is received. Because of the continuing possibility of blanking on-frequency signals and because the problem of off frequency interference will be substantially minimized, if the preselector as recommended by this study is installed, the SCR receiver can only be recommended if the above proposed modification (blanking by signal comparison) is made.

A second form of blanking under study at NRL makes use of post detection processing and blanking[12]. The processing for this system provides for digitalization of the signal and comparison of the return for successive sweeps.

The study conducted by NRL (Radar Division) explored two somewhat similar approaches to this form of blanking:

(1) Comparison of two successive sweeps for each range cell. For each range cell the smaller amplitude is selected.

(2) Compares the amplitudes of two successive sweeps to a fixed threshold for each range cell. If one amplitude is above the threshold and the other is below, the smaller amplitude is taken. Otherwise (both amplitudes above or both below the reference) the more recent amplitude is selected.

Both of these approaches operate on the principle that most interference is nonsynchronous and will not occur at the same time on successive sweeps. Thus large interference signals will be excluded from the display by comparing successive sweeps or successive sweeps to a separate threshold.

This approach works well in environments of low to moderate interference levels. It also requires that the RF-IF receiver be linear or, when saturated, have a fast recovery time in relation to the information resolution time (bandwidth) of the radar return. Frequent saturation coupled with long recovery time will lead to excessive blanking time or time with substitude information and consequent, significant loss of information. The present IF with a dynamic range as small as 10 dB for high gain and a maximum of 30 db in very susceptible to this problem. The present study suggests that the basic improvement recommended by this study, i.e., addition of a preselector and replacement of the mixer and IF (for high dynamic range) be carried out. With these modification which will exclude most interfering signals, and provide a high dynamic range through the detector, the benefit of post detection blanking can be meaningfully considered.

3.5 Matched Filter Operation.

A report on interference suppression cannot be concluded without mentioning possibilities for modification of the transmitter and receiver so that signal filter match is made possible. As indicated in section 2.3 the

present transmitted spectrum is spread around the operating frequency by more than a gigahertz. Though the set under test may have been in need of maintenance the extent of the specturm is a serious inhibitant to operating a number of systems within a fleet together. A common phemonum of SPS-10's operation in fleet configuration, is the appearance of "rabits" on the display. "Rabits", false indication that moves circumferentially around the screen, are due to interference between systems with similar pulse repitition rates.

Besides suppression of broad band interference, optimum operation of radar systems within an environment of significant electromagnetic interference requires match filter operations. For operations of the two modes, two spectrum widths are required, i.e., 1 and 5 MHz. For maximum signal usefulness for the system and minimum interference to other systems, the signal should largely be contained within these bandwidths for each mode. If the system and the system environment can tollerate wider bandwidths or longer transmissions (than the 0.2 and 1 us range resolution pulse lengths), coding can be used which will enhance the system signal to noise/interference ratio and enhance its ability to operate in a dense environment. Because coding combines coherently on match filter detection and noise and noncoherent interference combine noncoherently, the filter match signal achieves an advantage equal to the time-bandwidth product over those signals. Many coding techniques provide processing of twenty dB or more.

To provide for coding suitable for match filter operation would require replacement of the magnetron transmitter by a linear amplifier. It is, thus, beyond the scope of this program. The RF shelf design provided in this program will provide space for its future inclusion in the receiver. Thus, if the transmitter were later replaced with a linear amplifier, the receiver could accommodate inclusion with minimum additional changes.

3.6 Recommended Configuration

A broad range of areas of potential improvement has been discussed in the preceeding paragraphs, some beyond the scope of this program but of such a significant relationship their men was important. This section will provide a consolidation of the most directly relevant recommendations. This includes identification of a circuit and mechanical arrangement for the RF sections of the receiver. It also includes the very strong recommendation that the IF he replaced with a modern high dynamic range IF.

Figure 16 provides a consolidated circuit of the RF and IF portions of the receiver.

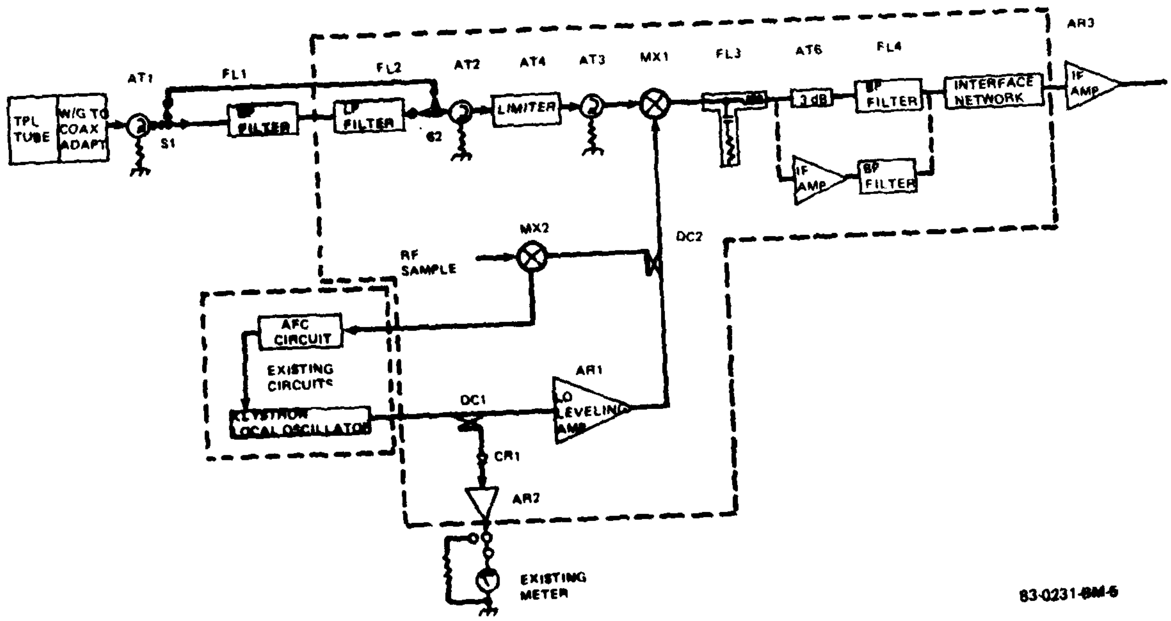


Figure 16 Block diagram showing elements of RF sections of SPS 10 receiver as recommended by study.

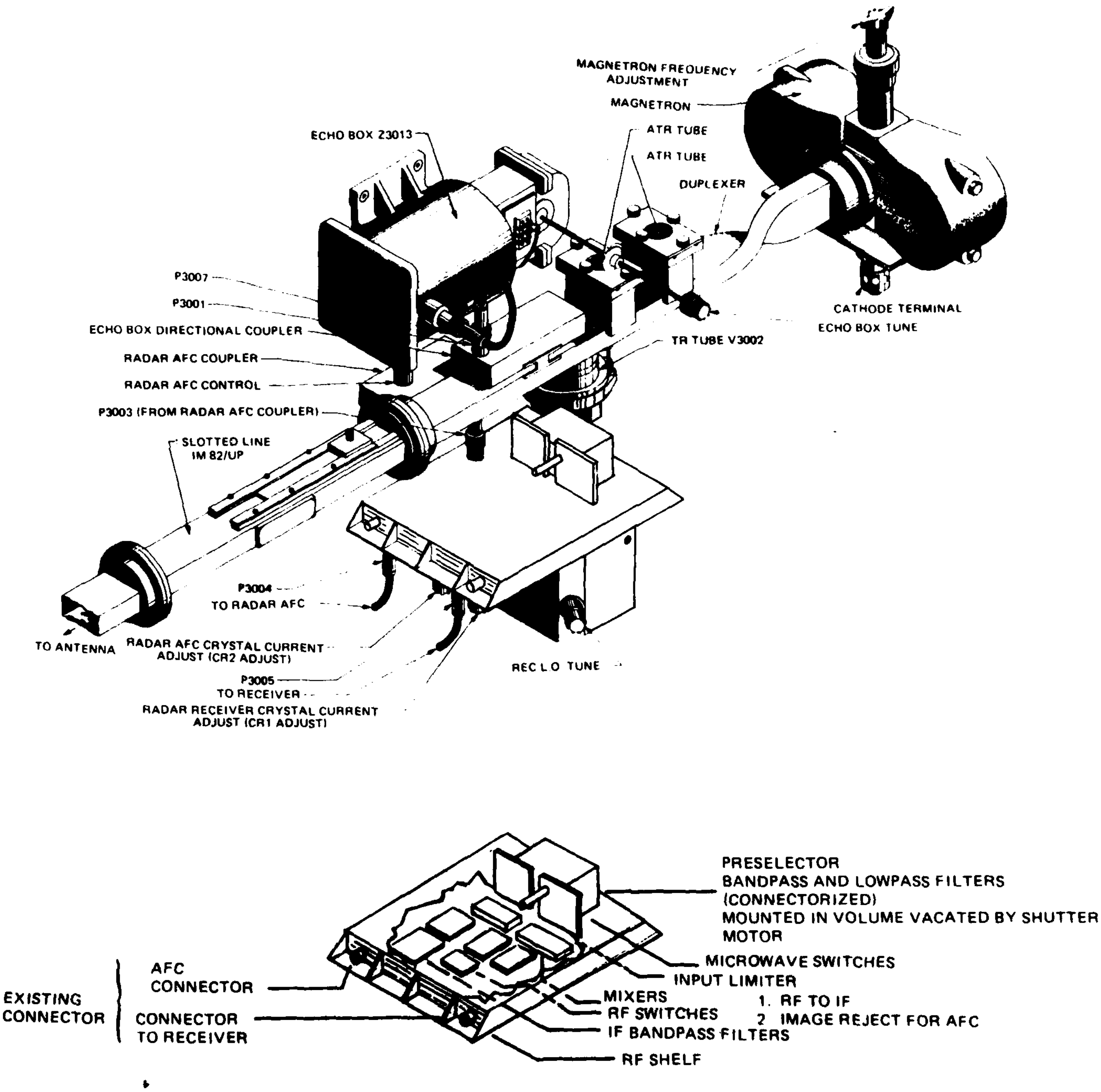


Figure 17 Mechanical configurations of RF sections of SPS-10 receiver as recommended by study.

4.0 Conclusions

The SPS-10 has been in the fleet for over 30 years and still serves navagational functions. The design is from an era when interference problems were much less intense and design selectivities and received performance is less stringent. As a result the SPS-10 receiver is susceptible to interference at virtually all frequencies above cutoff for the waveguide size from which it feeds. Specific examples of interference which victimize it were cited in the classified appendix to this report. Its broad selectivity characteristics have already been described in this report. Significant selectivity is provided by the IF to low level signals received. Because of the very low dynamic range of the IF, very little selectivity is provided for large signal level interfences within its operating band.

Much of the harmonic region of the operating band is open to interference penetration. Significant selectivity prior to elements which limit is only provided by the T-R assembly and there only by band edge skirts. the recommendations of the program serve to provide maximum front end selectivity allowable by component stabilities and high dynamic range operation to the point of final selectivity. Final selectivity recommended is maximum, including filterskirts, practical for required range resolution. Key elements of the recommendations were tested in breadboard form and found to provide substantial improvement in interfence suppression.

5. RECOMMENDATIONS

The following receiver modifications are recommended:

- o Provide narrow band frequency adjustable preselector filter. The recommended filter not only attenuates in the filter skirt to a maximum of 130 dB., its design provides isolation to 20 GHz.

- o Replace present mixer with high level doubly balanced mixer. The recommended mixer will provide improved noise performance needed to allow insertion of the preselector without loss of receiver noise performance. It will also minimize the tendency to saturate at the mixer on high level signals and minimize spurious interference between high level signals.

- o Selective 80 dB out-of-band IF rejection bandpass and high dynamic range operation. This will provide effective suppression of high level intertence which is on the skirts of the preselector filter recommended above. It will also prevent overloading the IF, presently extremely susceptible to overloading, and minimize the tendency to mask weak signals not in time coincidence with much strong interfence or radar raturn.

- o Replace AFC mixer with image rejection mixer. this will prevent the operator from inadvertently tuning the L.O. below the magnetron frequency rather than above where it is designed. Though the radar will work when the L.O. is tuned below the magnetron, its susceptability to interfence is much greater than when tuned above the magnetron frequency. Further, if the

increased IF selectivity recommended is provided, tune up with the L.O. below the magnetron would prevent effective reception even though the AFC current would read normally.

Elaboration and documentation of these recommendations have been carried out and are included in the main body of the report and following appendixes. In addition, there is a classified addendum which includes the actual frequencies of systems for which verified examples of interference victimizing the SPS-10 exists. The appendixes include relevent NRL and Westinghouse measurement and details of the analysis and recommendations for the system. The main body of the report purposely has been kept as readable as possible with most technical details contained within appendixes. Similarly, separately listing of classified inteferring frequencies from this report will allow maximum availability. Those needing the classified information can easily obtain access to the report through appropriate channels.

Form, fit and function (FFF) can be maintained at the operator level for all of the recommended variations except the frequency adjustable preselector filter. A deviation from FFF is recommended in the IF amplifier but can be eliminated with significant improvement still being achieved. Since, however, manual modification is required for the preselector filter, which is the most recommended change, if the preselector is accepted, all manual changes for other improvements could be carried through at the same time. Other manual changes will be minimized by making most recommended changes internal to directly interchangeable modules. Though some variations in substituted parts may be apparent to an experienced technican, module compatability can be complet between old and new. Only at the major repair level would manual changes be required for those changes.

6. REFERENCES

1. NAVSHIPS-91921(a) Instruction Book for RADAR Set AN/SPS-10, Bureau of Ships, Department of Navy, 4 May, 1953, with changes 3, 22 July, 1958; p. 2-18.

2. NAVSHIPS - 91921 (a), P.2-25.

3. R. Steel Classified Report, NRL.

4. R. Steel,"SPS-10 Receiver Susceptibility Characteristics" 17 Sept., '81 - (Supplied by NRL),

5. L. M. Orloff, "Intermodulation Analysis of Crystal Mixer," Proc. IEEE, Vol., No.2, pp. 173-179; February, 1964.

6. R. Meisnor, NRL furnished data.

7. B. Bossar, L. Becker, R. Ernst, E. Mackard, W. Y. Pan, B. Perlman, S. Perlow, P. Torrione, S. Yuan, "Interference Reduction Techniques for Reciever," "TR-ECOM 02345-F Final Report, Contract DA-36-039-AMC-02345(E), USAEC, Ft. Monmouth, N.J.; July, 1963 - Nov. 1966 AD-810 846.

8. J. Borkowski, "Test Data, Investigation and Changes to Radar Set, ANISPS-10 ( ) Fitted With Interference Blankes, MX9281/SPS-10, TR 21331, NRL, 25 February, 1981, P. 62.

9. NAVSHIPS-91921(a) p. 2-33.

10. A. H. Light, "Shipboard Electromagnetic Compatibility In Procurement Program, (SEMCIP) Radar Evaluation Results Aboard USS Mount Whitney. (LCC-20), Electronics Systems Dept., Dahlgreen Laboratory, Dahlgreen, Va., 22443, March 1977, AD-C0111011 p. 7.

11. Conduct A Fleet Operational Investigation of the Spectrum - Centered Receiver, Final Report on Project F/0169 F/64, By Commander Operational Test and Evaluation Force, Norfolk, VA 23511, AD-257609 L.

12. B. R. Jarrett, G. J. Linder, "Interference Suppression Technique Utilizing Nonsynchronous Video Data Processing, " Disclosure, NRL.

7. APPENDIX

7.1 Summary of Key Measurements

Data used in drawing conclusion on the program was taken from numerous sources. Summarized here is this data extracted from data taken by NRL prior to the program and by Westinghouse with NRL corporation during this program.

7.1.1 Pre-program Data

The following data are extracted from accounts of measurements taken by NRL prior to the program and provided by NRL at the beginning of the program. Tables 2 and 3 are noise figure and spurs close to the operating band (near band). Figure 18 gives the frequency response of the duplexer, the only pre-mixer isolation provided by the system except below band due to waveguide cut-off.

7.1.2 Initial Program Measurements

The following is a summary of measurements made on the SPS-10 at Chesapeake Bay Detachment of NRL by Westinghouse with support and cooperation from NRL personnel. Measurements were conducted October 9 and 12, 1981 and served as a significant portion of the data basis and confirmation of other data on which the study was based

The objectives were to:

(a) determine extent of harmonic response
(b) measure in-band responses
(c) examine effects when receiver is saturated (most non-linear)
(d) make observations on system response

7.1.2.1 Harmonic Response

Receiver L.O. set a 5730 Mhz
Mixer crystal at middle of "good" range
Gain control set for some "grass"
Using an adaptive network of couplers and tapers, the signal generator was swept from 18 GHz to 2 GHz.
Responses were measured at

freq(MHz)	Level*(-dBm)		Remarks
17,219	-22	3x1	3rd Harmonic Response
17,160	-23		
11,517	-31	2x1	2nd Harmonic Response
11,488	-33		
11,428	-32		
11,400	-34		
5,760	-47		Image Sideband
5,699	-47		Signal Response
2,880	-		Not able to measure
2,800	-		

within 2 GHz to 18 GHz, extremely low level signals were observed at

15,078 MHz
13,567 MHz
8,290 MHz

TABLE 2
NOISE FIGURE

LO GHz	Noise Figure Double Side Band	Single Side Band
5.5	18	15
5.6	16	13
5.7	15.7	12.7
5.8	15.8	12.6

TABLE 3

NEAR BAND SPURIOUS, LO FREQUENCY 5570 MHz

Signal		Frequency MHz	Sensitivity dBm
Reserved Signal		5540	-85
Image		5600	-85
Harmonic Spurs	2x2	5550	-45
	3x3	5550	-45

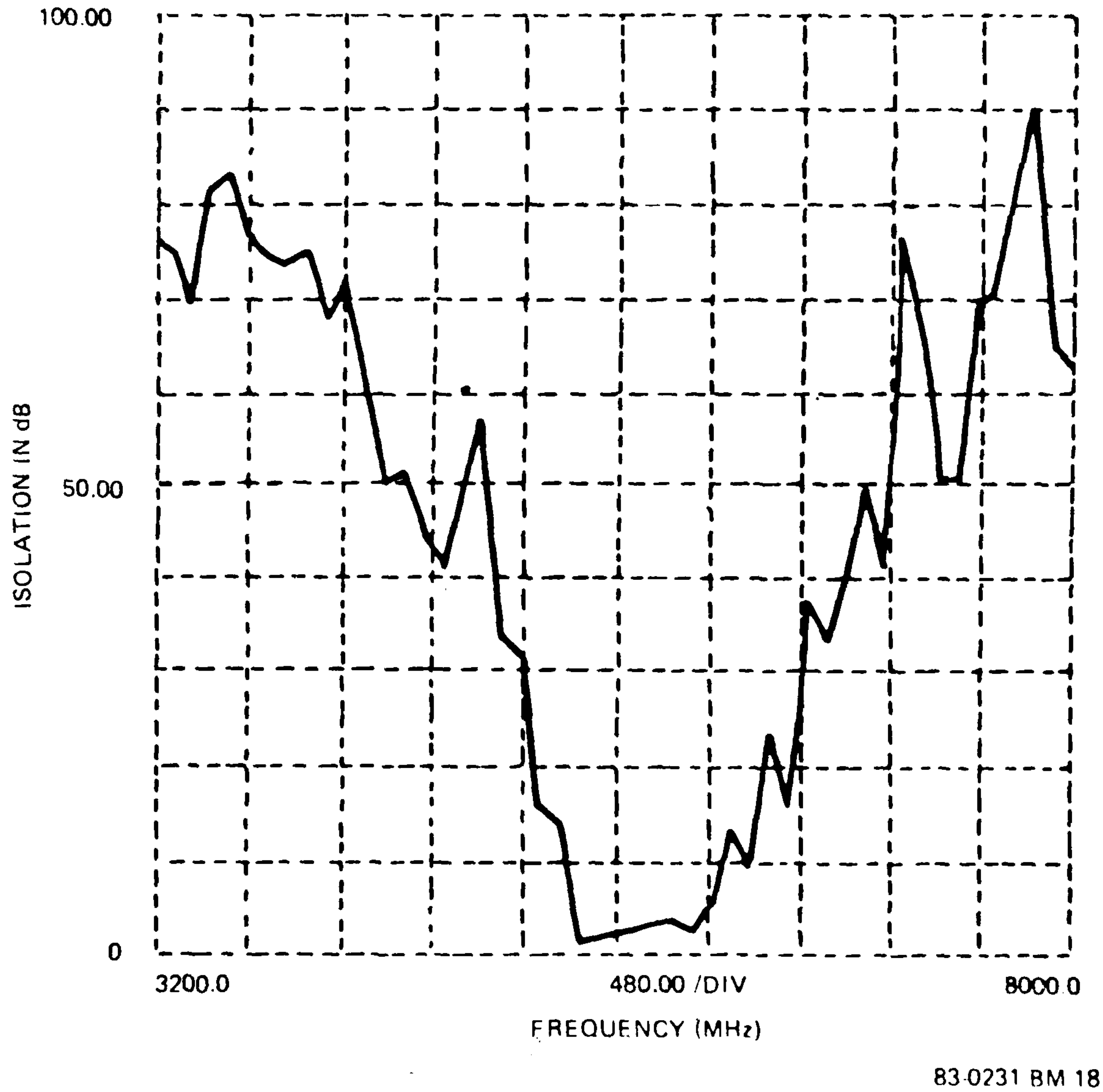


FIGURE 18 BANDPASS OF DUPLEXER FROM 3200 TO 8000 MHz

They tended to be low level, stable and repeatable but no explanation, save speculation on sig. gen. outputs, seems reasonable.

*(Levels) - These are arbitrary. At the signal frequency, and this receiver gain adjustment, the signal output was set for one vertical scale division in height. The power input at the harmonics was then adjusted to match this division and the coupling network (tapers and couplers) was subsequently calibrated out. (Network moded at numerous frequencies.)

The attenuation was too great at 2880 MHz to calibrate the C-band transition. In a subsequent telephone coversation with R. Maixner, it was pointed out by him that this may be a peculiarity of the hp digital sig. gen. In fact, we were looking at the second harmonic of 2880 MHz.

7.1.2.2 Measuring H-band Response

As noted, both signal frequency and the image come thru at equal levels.

Conversion efficiency at normal at -84dBm (WBF-5 MHz IF BW)

With L.O. set normal (mid "good" range) any two other signals 30 MHz apart gives an output (signals anywhere in frequency band.)

At low signal levels (-40dBm) no spurious responses were observed.

7.1.2.3 Mixer Saturation Effects

First L.O. coupling was increased to put the X-TAL current at max red condition.

Signal level of -40dBm was adjusted thru the frequency band. At the signal and image frequencies, the IF broke into oscillation.

IF was observed that either lowering the receiver gain (some unknown amount) or reducing the receiver into signal could stop these oscillations. (approx. -15dB).

Next the L.O. was completely decoupled and a coaxial coupler (10dB) was used to feed both L.O. (hp 618b) and signal (hp sw. gen.) into the mixer from the front end. Assuming 2 dB loss tot he mixer, the following data was taken.

L.O. Power Signal Power	Output
0 dbm	
-20 dBm	Normal
0 dbm	
-10 dBm	"Oscillation" (1)
	(1) Oscillation removed by reducing gain
+3 dBm	
-20 dBm	Normal gain could be increased to cause oscillation.
+3 dBm	
-10 dBm	Oscillation (1)
+10 dBm	
-20 dBm	Oscillation (1)
+10 dBm	
-20 dBm	Oscillation (1)

The L.O. was set for +10dBm, signal at -40dBm, gain for some grass. No spurious response was found in-band.

7.1.2.4 Observations

Operation of the system is to set to arbitrary preferences. Response is then varying.

When the mixer crystal was changed, and the tests of Part C re-ran, there was no change.

Recommendation:

Concentrate on removing In-band Interference (Image, etc.) IF BW could be reduced to eliminate close in ±10 MHz interference.

7.1.3 Final Program Measurements

The appendix includes measurements taken both at Chesapeake Bay Detachment and at Westinghouse to confirm elements of recommendation. Measurements taken at Chesapeake Bay Detachment were by Westinghouse with NRL support and cooperation.

7.1.3.1 Tests Conducted At Westinghouse

Limited pre and post tests were conducted at Westinghouse respectively, on the preselector and mixer. Data on the preselector was taken at 5 MHz intervals between 5450 and 5825 MHz and at 1 MHz intervals between 5615 and 5645 MHz. Center frequency as found to be between 5629 and 5630 MHz. Data provided by the maunfacturers shows the isolation to be greater than 70dB for frequencies above those tested.

TABLE 4
ISOLATION AND PHASE ANGLE OF PRESELECTOR BETWEEN 5450 AND 5828 MHz

MAX VSWR CIRCLE= 1.0 FREQ=5450.MHZ TO 5825.MHZ REF=0.000

FREQ	VSWR	COND	SUSC	GAIN	ANGLE	
5450.	****	-1.00	-2.77	-7.1	-86.2	-86.2
5455.	****	-.93	-2.76	-71.[illegible]	-5.5	-5.5
5460.	****	-.96	-2.78	-27.4	4.5	-9.5
5465.	****	-.96	-2.67	-64.2	169.1	169.1
5470.	****	.63	-2.72	63.6	61.2	61.2
5475.	****	-.60	-2.64	-76.2	164.7	164.7
5480.	****	-.48	-2.59	-66.2	157.4	157.4
5485.	****	.36	-2.60	-61.4	-117.7	-117.
5490.	****	.33	-2.56	[illegible].7	-40.8	-40.
5495.	****	-.27	-2.56	29.7	47.4	-47.4
5500.	****	-.25	-2.52	-68.0	-55.4	-55.4
5505.	****	.30	-2.44	-75.9	-60.1	-60.1
5510.	****	-.27	-2.43	-55.6	131.5	131.5
5515.	****	.22	-2.41	-67.8	113.1	113.1
5520.	****	-.31	-2.32	-56.7	-116.1	-116.1
5525.	****	-.25	-2.29	-58.9	44.4	44.4
5530	****	.25	2.23	-89.1	78.1	-7[illegible].1
5535.	****	.22	-2.17	55.5	[illegible].1	-65.1
5540	****	-.25	-2.12	-86.8	-87.5	-87.5
5545.	****	.27	-2.04	[illegible].1	[illegible]	88.9
5550.	****	.28	-1.96	71.5	65.4	65.4
5555.	****	.28	-1.87	-80.1	90.8	90.8
5560.	****	.28	-1.78	-55.0	-134.4	-134.4
5565.	****	-.29	-1.70	-55.2	[illegible].1	49.1
5570.	****	.24	-1.62	67.3	69.3	69.[illegible]
5575.	****	.30	-1.52	[illegible]	[illegible].0	66.0
5580	****	.25	-1.48	64.7	-116.3	-116.[illegible]
5585.	****	-.24	-1.37	-59.1	60.6	60.6
5590.	****	[illegible]	-1.31	74.3	[illegible]	55.0
5595.	****	.17	-1.21	[illegible].3	12[illegible].2	12[illegible]
5600.	****	.13	-1.12	-76.5	46.1	46.1
5605.	****	-.09	-1.00	6.6	127.7	127.7
5610	****	[illegible]	.92	52.4	1[illegible].6	123.6
5615	47.4	.93	-.55	-38.7	81.6	81.[illegible]
5620.	2.55	.38	.06	-12.9	-22.0	-22.0
5625.	1.55	1.07	-.45	4.0	138.7	138.[illegible]
5630.	1.42	1.34	-.22	4.4	-12.0	-12.0
5635.	1.57	1.53	-.19	-4.0	-169.9	-169.9
5640.	3.10	.80	1.05	-15.3	-16.8	-16.8
5645.	****	-2.15	9.80	-29.4	-103.8	-103.9
5650.	****	-5.90	-7.77	-49.2	-157.5	-157.5
5655.	****	-2.10	-4.55	-76.4	171.3	171.[illegible]
5660.	****	1.19	-3.64	-90.3	157.9	157.9
5665.	****	-.95	-3.19	-74.4	149.8	149.8
5670.	****	-.85	-2.79	-79.4	36.5	-36.[illegible]
5675.	****	-.69	-2.67	-70.7	-34.8	-34.[illegible]
5680.	****	-.67	-2.42	-69.6	-33.0	-33.0
5685.	****	-.56	-2.28	-80.2	147.6	147.6
5690.	****	.52	-2.13	-77.4	145.4	145.4
5695.	****	.47	-2.01	57.6	-41.8	-41.8
5700.	****	.45	-1.91	66.9	[illegible]1.3	-51.3
5705.	****	-.40	-1.96	-71.9	117.4	117.4
5710	****	-.34	-1.82	-59.1	70.4	70.4
5715.	****	.32	-1.80	94.5	[illegible]	101.1
5720.	****	.34	1.76	76.4	[illegible].5	-93.[illegible]
5725.	****	.31	-1.72	[illegible].2	84.2	-84.[illegible]
5730.	****	.32	-1.67	[illegible].2	95.4	95.4
5735.	****	-.31	-1.63	-96.1	91.6	91.6
5740.	****	.30	-1.59	70.7	[illegible].0	85.0
5745.	****	-.27	-1.53	[illegible].6	105.9	-105.9
5750.	****	-.21	-1.54	55.6	-136.3	-136.3
5755.	****	-.19	-1.52	-6.6	-125.9	-125.0
5760.	****	-.17	-1.50	97.0	-132.7	-132.7
5765.	****	-.12	-1.50	-77.7	-139.0	-139.0
5770.	****	-.09	-1.50	-60.1	-37.4	-37.4
5775.	****	-.06	-1.48	5[illegible].7	170.9	-170.9
5780.	****	.03	-1.49	[illegible].9	29.3	29.3
5785.	175.	.02	-1.47	66.2	[illegible]1.9	-61.8
5790.	[illegible]	[illegible]	1.45	[illegible].0	[illegible].7	159.[illegible]
5795.	[illegible].9	.07	1.4[illegible]	[illegible].4	[illegible]	1[illegible]

TABLE 4 Con'd.

5800.	36.3	.08	-1.39	-74.7	8.4	8.4
5805.	34.1	.08	-1.37	-96.7	-177.3	-177.3
5810.	53.1	.05	-1.33	-74.0	-.4	-.4
5815.	55.4	.05	-1.29	-84.0	4.5	-4.5
5820.	97.9	.03	-1.26	-82.3	172.5	172.5
5825.	$$$$	-.01	-1.22	65.5	-79.9	-79.9

Doc. Id. 7283c

TABLE 5

VSWR ISOLATION AND PHASE ANGLE PRESELECTOR BETWEEN 5615 AND 5645 MHz

MAX VSWR CIRCLE= 1.0 FREQ=5615.MHZ TO 5645.MHZ REF=0.000

	FREQ	VSWR	COND	SUSC	GAIN	ANGLE	
A	5615.	30.5	.04	-.59	-36.1	92.1	92.1
B	5616.	17.7	.07	-.51	-32.0	71.0	71.0
C	5617.	12.2	.10	-.41	-27.8	55.3	55.3
D	5619.	7.88	.14	-.29	-22.7	34.6	34.6
E	5619.	4.69	.22	-.13	-17.4	10.4	10.4
F	5620.	2.61	.39	.05	-12.3	-23.3	-23.3
G	5621.	1.49	.69	.12	9.4	-68.1	-68.1
H	5622.	1.09	.91	.01	-5.4	-113.7	-113.7
I	5623.	1.11	1.07	-.09	5.4	-153.4	153.4
J	5624.	1.36	1.19	-.29	-4.9	169.5	169.5
K	5625.	1.50	1.09	-.42	-4.6	136.9	136.9
L	5626.	1.45	.97	-.37	4.4	104.6	104.6
M	5627.	1.29	.98	-.24	-4.2	73.8	73.8
N	5628.	1.18	1.09	-.15	4.1	43.5	43.5
O	5629.	1.23	1.24	-.14	[illegible]	13.7	13.7
P	5630.	1.30	1.32	-.20	4.2	14.9	14.9
Q	5631.	1.41	1.31	-.24	-4.1	-44.9	-44.9
R	5632.	1.39	1.33	-.19	4.2	-73.9	-73.9
S	5633.	1.42	1.39	-.14	-4.4	103.0	103.0
T	5634.	1.43	1.46	.14	4.6	-134.5	134.5
U	5635.	1.50	1.47	-.16	-4.7	-166.2	166.2
V	5636.	1.43	1.41	-.13	5.1	159.2	159.2
W	5637.	1.35	1.34	-.06	[illegible]	120.6	120.6
X	5638.	1.19	1.17	.06	[illegible]	79.0	79.0
Y	5639.	1.55	.94	.43	-9.5	30.7	30.7
Z	5640.	2.99	.85	1.05	-14.0	-11.4	-11.4
a	5641.	5.24	.94	1.79	19.8	-43.5	-43.5
b	5642.	9.46	1.14	2.73	-25.1	-64.4	-64.4
c	5643.	13.0	1.54	4.09	-30.4	-80.3	-80.3
d	5644.	17.9	2.40	6.03	-34.9	-93.8	-93.8
e	5645.	26.0	4.18	9.50	-38.6	-101.4	101.4

The mixer test of spurious was conducted at the one dB compression point which is +9dBm. This is just 4dB lower than the local oscillator level. The spurious was then measured for a signal of -10dBm. On the second test no spurious could be measured which indicated it was suppposed by more than 60dB

TABLE 6
MIXER TEST FOR SPURIOUS

L.O.	5560 MHz	@	+13dBm
RF	5630 MHz	@	+9dBm (1dB compression unit)

Output below signal

2x2	-42dB	5x5	-45dB	8x8	-60dB
3x3	-30dB	6x6	-60dB	9x9	-60dB
4x4	-38dB	7x7	-42dB	All Other	-60dB

7.1.3.2 Chesapeake Bay Detachment Tests

The object of these tests was to confirm effects of spurious suppression by using preselector and high level mixer. The full extent of measurements intended were not taken on both, primarily because of the inability in providing an acceptable match between the experimental mixer and the IF in the time available for the tests. To the extent conducted tests confirm the spurious rejection benefits of the preselector. The mixer tests , however, were inclusive. Tests taken at Westinghouse show the mixer to have excellent (60dB) suppression of spurious for signals below saturation. The lab saturation level of the test mixer was +9dBm for an L.O. level of +13dBm.

It should be noted that on initial tune-up the Chesapeake Bay Detachment technician set the local oscillator below rather than correctly above the signal frequency. Since this condition was identified by the NRL engineer on his arrival and before any recorded tests were taken, none of the results reflect this condition. That it occurred is significant in that it confirms the susceptibility of the system to this form of misalignment and the usefullness of a program recommendation that AFC mixer has replaced by a image suppression mixer. This recommendation is covered in section 2.2 and 3.3.

Measurement of spurious suppression of preselector was made with pre-selector at input to SPS-10. Response of preselector in 7.1.3.1 TABLE 4 Note center frequency of preselector filter was 5630 MHz for all tests.

```
 ________________     ________________     ________________     ________________
|     SIGNAL     |   |  PRESELECTOR   |   |    COAXIAL     |   |     INPUT      |
|   GENERATOR    |---|     FILTER     |---|       TO       |---|       TO       |
|________________|   |________________|   |__WAVEGUIDE_____|   |__DUPLEXER______|
```

1. <u>IMAGE SUPPRESSION</u>

Transmit Frequency = 5630 MHz
L.O. = 5660 MHz
Results: Image down greater than 50dB. Signal generator did not have enough power to produce image through filter.

2. TWO TONE SUPPRESSION

A. 5615 MHz pulsed
5645 MHz CW
L.O. = 5660 MHz
Results: The 30 MHz signal processor from the two signals was down 80dB with the filter.

B. 5620 pulsed
5640 CW
L.O. = 5660
Results: The 30 MHz signal produced was down 30dB.

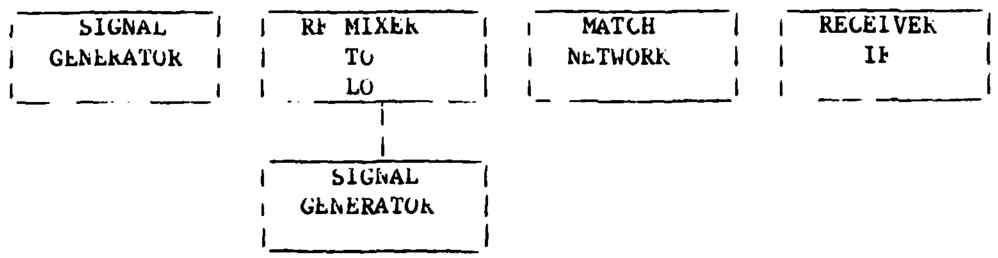
Mixer tests were conducted on the actual radar mixer and a high level balanced mixer consistent with the recommended modifications. However, for the time available for measurements, it was found to be impossible to provide an adequate match between the high level mixer and the IF. In the actual hardware the match is divided between the RF shelf and IF strip. The signal required for 1dB saturation of the high level was over an order of magnitude greater than the existing mixer. However, the acutal value would have little significance because of the miss match of the high level mixer to the existing IF. Measurements made at Westinghouse (Section 7.1.3.1) show the 1dB saturation to be at +9dBm.

1. EXISTING MIXER

Results: At the point where the receiver saturated the opposite 3x3 product was down 32dB. No other products could be measured because of the output power of the signal generators used was not great enough.

2. HIGH LEVEL MIXER

L.O. Level = 13dBm
L.O. = 5660



Results: At the point where the receiver saturated the opposite 3x3 product was down 31dB. A substantial mismatch ws noted which must have degraded mixer performance.

7.2 SHELF DESIGN

7.2.1 Preselector

Design considerations are briefly summarized here:

- o 3db Bandwidth - The magnitude drift is specified as ±7.05 MHz. To allow deteriation this figure was increased slightly to ±75 or a 15 MHz bandwidth. For this bandwidth a 6 section Butterworth filter will suppress the image (-60 MHz) over 90db.

- o Harmonic Suppression - a low pass filter is cascaded with the bandpass filter. Minimum suppression of 70dB was specified.

- o Design - Multipole Butterworth was investigated. Example characteristics are illustrated. Skirts of multipole designs as shown in Figure 19. Filter must be capable of being single knob tuned though test filter is fixed tuned.

- o Connections - Co-axial corrections were specified to fit replacement RF shelf geometry concepts.

7.2.2 High Level balanced Mixer

Figure 20 shows the higher order mixer products based on L.O. level and the assumption of an intercept point 10dB above the L.O. shows minimum detectable signals for the 2x2 and 3x3 products to be -40dBm and -23dBm, respectively for an L.O. power of 0dBm. This is not very different from the 2x2 measured for the SPS-10 by NRL (TABLE 3). It is higher, however, than the 3x3 measured by NRL. Figure 20 does show what will occur for a higher level mixer. For an L.O. power of +15dBm . Because the recommended mixer is balanced, the 2x2 is suppressed by an additional 20dB the actual 2x2 and 3x3 minimum detectable signals would be -12dbm for an additional 33dB suppression over the present mixer.

7.2.3 IF Preselector Filter

Two types of preselector filters were considered i.e., LC and SAW. Example band pass characteristics are shown in Figure 21 for these for the wideband mode superimposed over the present with band mode characteristics for reference. Though shown for the wideband mode, similar results could be achieved for the narrow band mode. The advantage of LC over SAW is the lower insertion loss. The advantage of SAW over LC is the steeper skirts. A possible position for the IF preselector filters is shown as the RF shelf along with required for amplifiers to compensate for the loss.

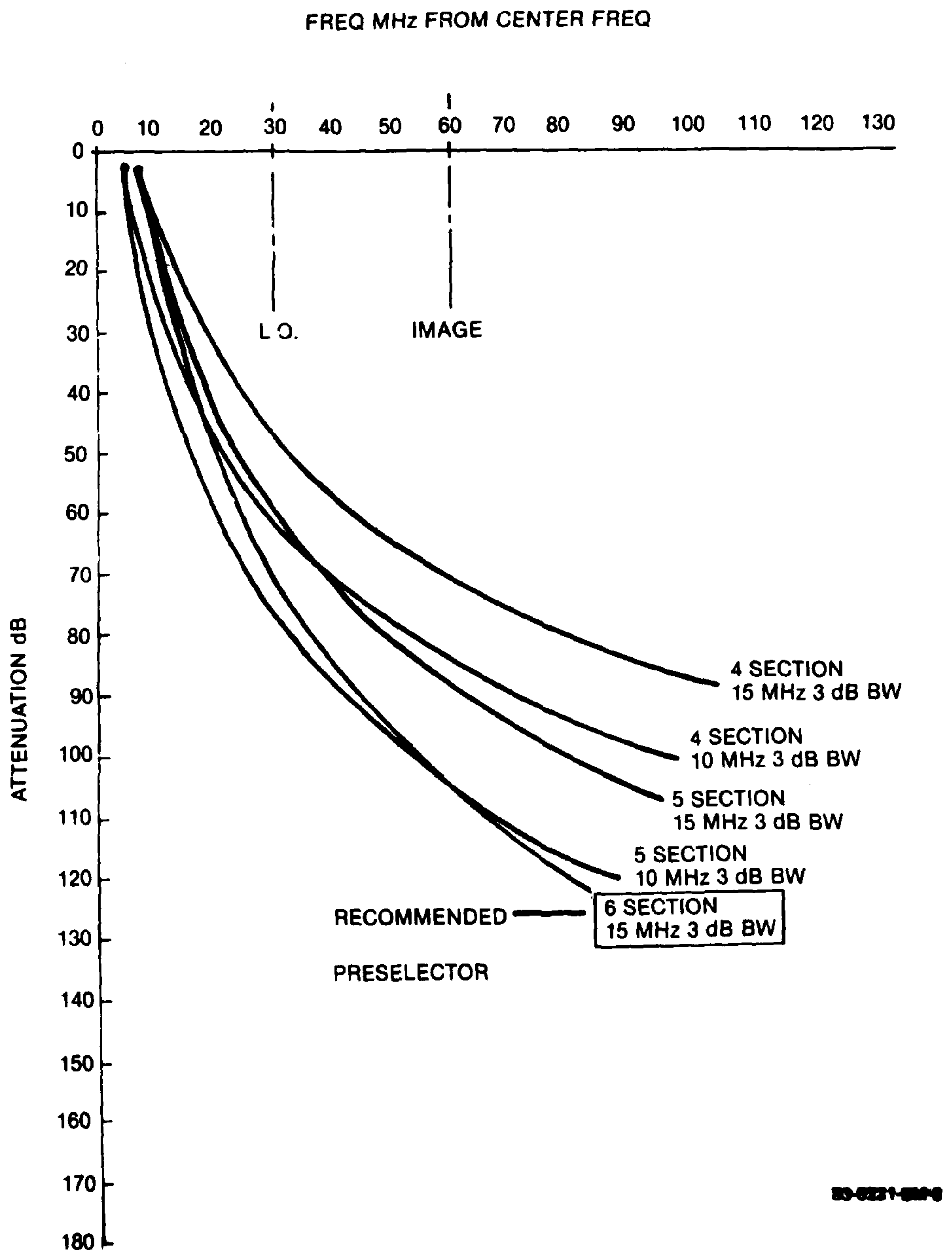


FIGURE 19 SKIRTS OF MULTIPLE BUTTERWORTH CONSIDERED FOR PRESELECTOR

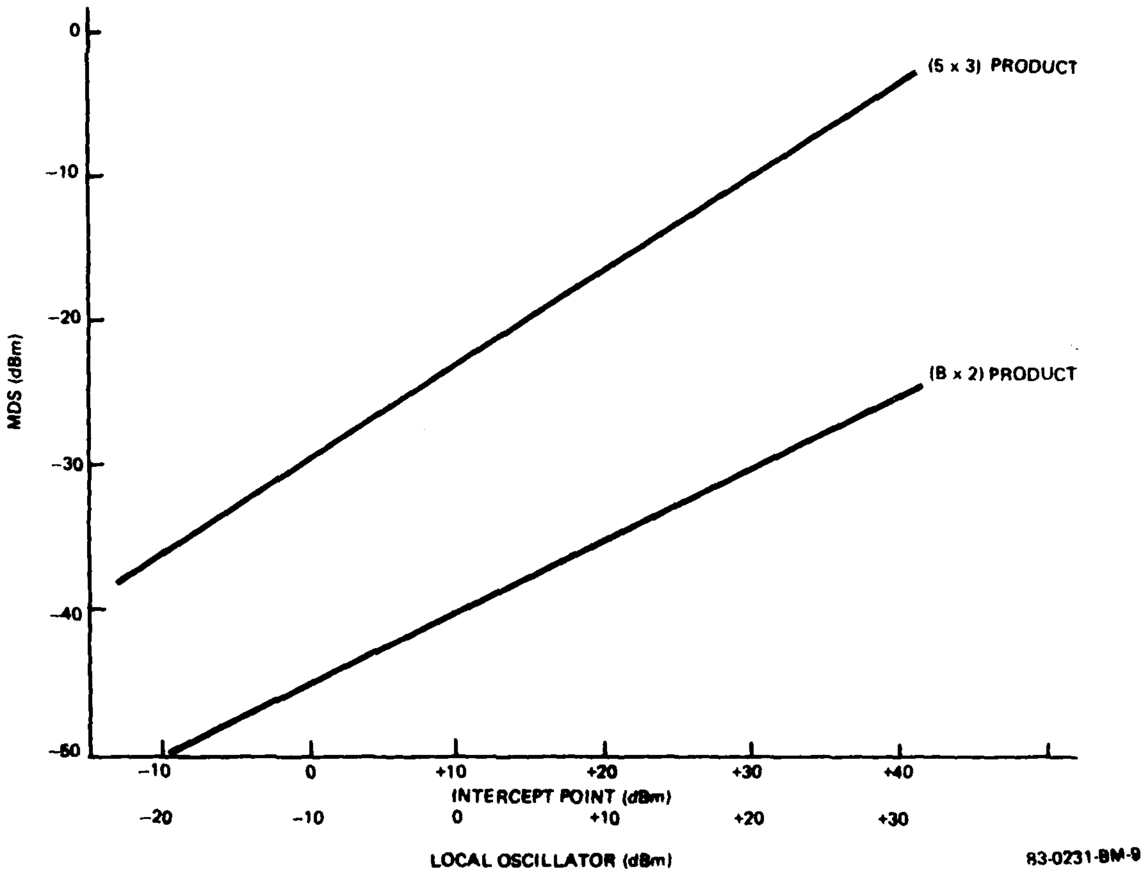


FIGURE 20 2x2 AND 3x3 MIXER PRODUCTS

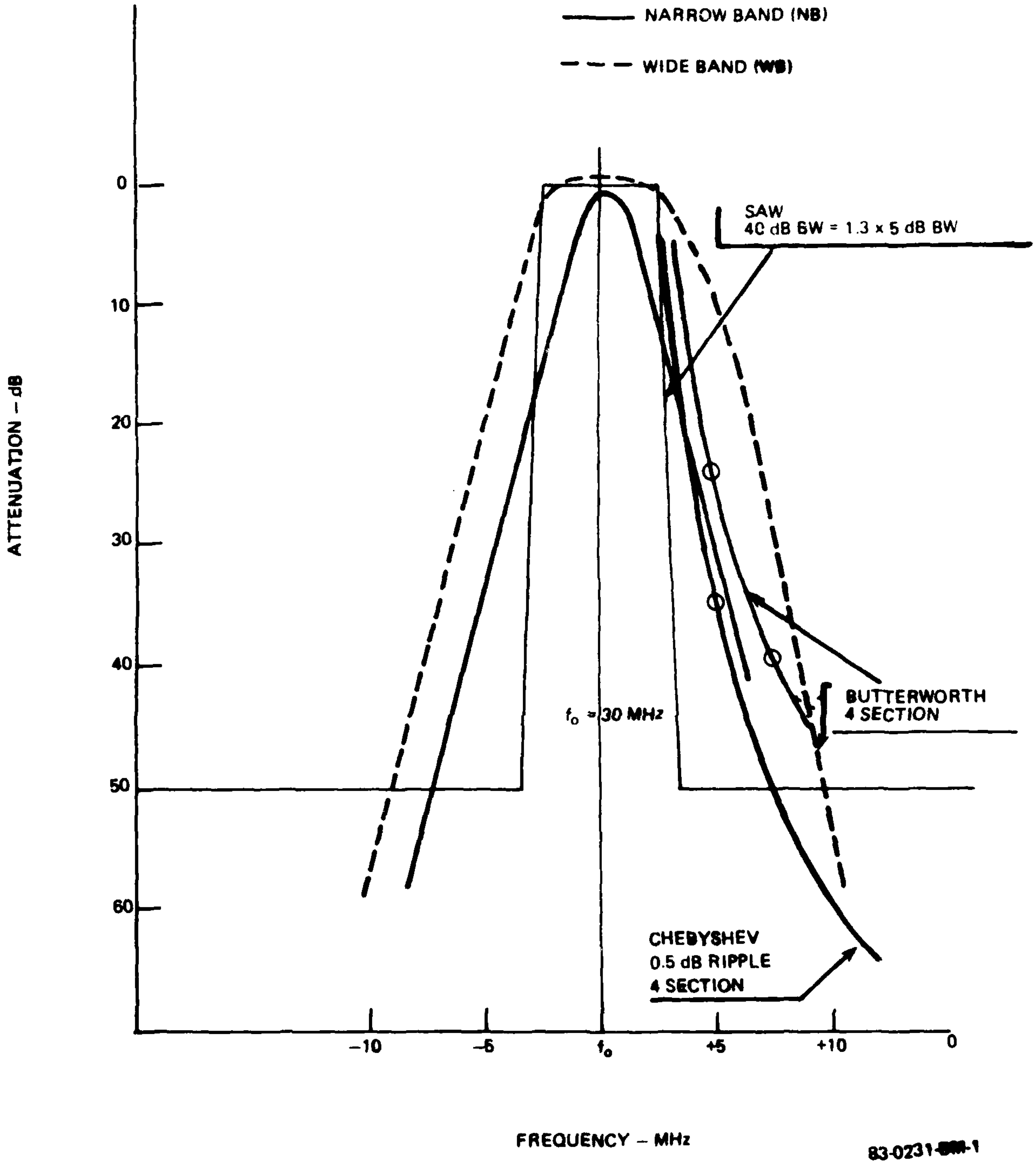


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FIGURE 21 IF Preselector Filter Options for Wideband Mode

DAT

FILM

7-8